CCAR and Beyond

Capital Assessment, Stress Testing and Applications

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Acknowledgements from the Editor

The process of conceiving and editing a book on capital adequacy assessment and stress testing could well have been a challenging and stressful one. Instead, the work turned out to be a wonderful experience thanks to the great group of people with whom I had the good fortune and honour to work with during this project. First, I owe deep gratitude to the editorial staff at Risk Books: Sarah Hastings for suggesting the possibility; Amy Jordan for effectively co-editing the book with me; and Lewis O'Sullivan for the careful final touches. Second, I would like to thank risk management colleagues at various banks that I have worked with on CCAR-related projects; I have learned a great deal from them. Third, I acknowledge the encouragement and support from my colleagues at Moody's Analytics. Additionally, the support of my family throughout the project has been essential, as they afforded me the weekends and evenings to focus on the work. Finally, and above all, I thank the contributors for generously sharing their insights and perspectives, especially under tight timelines, and for giving me the opportunity to work closely with such an outstanding group of experts.

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Introduction

Jing Zhang

Moody's Analytics

Stress testing, regulatory or internally driven, was not new to banks before the onset of the financial crisis in 2007–08. Banks had been routinely conducting capital adequacy assessment and planning long before the crisis. However, the financial crisis made starkly bare the deficiencies in these practices and processes, as well as the opaqueness of risk in the balance sheet. In 2009, at the height of the crisis, the US Treasury and the Federal Reserve initiated the Supervisory Capital Assessment Program (SCAP) to assess the capital adequacies of the largest US bank holding companies (BHCs). These banks were subjected to a rigorous review, which included stress testing, to measure the potential loss and resulting capital shortfall. The results of the programme were announced publicly. Banks deemed inadequately capitalised were required to raise capital in the marketplace, with the US Treasury acting as a backstop. The financial markets and the public reacted positively to the programme and disclosure, leading to the gradual restoration of public confidence in the US banking system.[1]

Since this success, SCAP has evolved into the Comprehensive Capital Analysis and Review (CCAR), aimed at large and complex BHCs with US$50 billion or more in assets. This annual exercise strives to ensure such banks have robust, forward-looking capital planning processes that account for their unique risks and sufficient capital to operate under different stress levels. As part of the exercise, the Federal Reserve evaluates institutions' capital adequacy, internal capital adequacy assessment processes and their plans to make capital distributions, such as dividend payments or share buy-backs.

A key part of CCAR is a supervisory stress test supporting the Fed's analysis of the firm's capital adequacy, in addition to qualitative assessment. Additionally, the Dodd–Frank Act (DFA) requires the Federal Reserve to conduct annual supervisory stress tests under three scenarios – baseline, adverse and severely adverse – and to publicly disclose the results. Furthermore, the DFA also requires all federally regulated financial companies with US$10 billion or more in consolidated assets to conduct their own internal stress tests annually, and to publicly disclose the results of these tests under the severely adverse scenario.

Stress testing and CCAR are making a profound impact on large banks, as well as the regulators, in the US. Since the first CCAR in late 2010, these banks have invested significant resources in the data, systems, models, processes and governance needed to meet the challenges of fulfilling CCAR requirements. Additionally, senior management and boards of directors are required to review and approve capital plans before submitting them to the Fed. Regulators have shifted the focus of these programmes from crisis management to forward-looking assessments of both individual banks' risk and systemic risk assessment, and as a means of prodding banks to improve their risk management and internal controls. CCAR's impact is global. Similar supervisory stress testing and capital assessment programmes have been conducted in other parts of the world, with varying degrees of success. As of late 2013, the UK Prudential Regulation Authority (PRA) is preparing a stress-testing regime similar to CCAR for large UK banks.[2] In 2014, the European Union will conduct a fresh round of stress testing on over 90 European banks after concluding their Asset Quality Review (AQR) programme.[3] CCAR is emerging as the standard for supervisory programmes, one that many regulators around the global would like to emulate.

CCAR has quickly become the most dominant regulatory regime for US banks. Of the new regulatory requirements BHCs must address, CCAR is widely considered to have the greatest influence on bank's risk management and business practices. Against the backdrop of this profound impact, there have been few, if any, systematic treatments of the subject. This book, with its 15 contributed chapters, represents a timely, concerted and collective effort to provide comprehensive and authoritative coverage of CCAR and its implications. It is designed to provide a unique source of information and insight from key figures involved in CCAR. The contributors explain the context and evolution of CCAR and stress testing, showcase industry perspectives and best practices, and discuss CCAR's implications and impact on risk management practices. The authors, with deep experience and expertise in their respective areas, represent leading experts from regulatory bodies, banks, consulting firms and analytics providers. Collectively, their views and perspectives are broad, complementary and insightful.[4]

As CCAR is primarily regulatory-driven, regulators are uniquely qualified to provide insights from their policy work and supervisory experiences, observing the cross-sectional practices by banks. Our contributors from various CCAR banks provide direct perspectives based upon their bottom-up and on-the-ground experience, while authors from consulting and analytics firms address the comparative landscape, utilising their experiences in working with multiple banks on CCAR-related projects.

CCAR and Beyond begins with an overview of the history and evolution of SCAP and CCAR. After laying out the regulatory context and supervisory expectations, subsequent chapters detail banks' perspectives on the challenges of meeting CCAR requirements and enterprise-wide stress testing, as well as the implications. Next, a number of chapters are dedicated to the implementation and practical aspects of CCAR and stress testing, including data and system infrastructure, and modelling and quantification. A section on modelling covers loss estimation for major asset classes (corporate, commercial real estate (CRE) and retail) and risk types (credit, market and operational risk), as well as modelling revenue and expense. After covering implementation, we address the important topic of governance and control. A substantive chapter, which amounts to a semi-summary, provides an overview and compares the different capital management initiatives that exist within the large banks in addition to CCAR. The book ends with a chapter offering an international perspective on the subject. For the readers primarily interested in capital assessment and management and their business implications, we recommend focusing on Chapters 1, 2, 3, 13 and 14. Readers interested in implementation and practical aspects should gain most from Chapters 4–12. To help readers navigate the book in more detail, we will next provide an overview of each chapter.

In opening, Tim P. Clark and Lisa H. Ryu from the Federal Reserve Board describe the evolution of stress testing and related supervisory capital assessment programmes since SCAP in 2009, and provide historical context for CCAR. They also discuss key features of, and considerations for, supervisory stress tests, as well as briefly discussing how supervisors assess BHC stress tests and capital planning in CCAR. Given the public nature of the review programme, they focus on the role of disclosure – a key feature of supervisory stress tests and CCAR. Two of the main themes of the chapter are that CCAR is more than stress testing and should be viewed as a complement to, and not a substitute for, regulatory capital requirements that assess BHCs' capital adequacy at a given point in time.

Next, Chapters 2 and 3 provide perspectives from financial institutions. In Chapter 2, Andy McGee and Ilya Khaykin discuss the evolving role of enterprise-wide stress testing. Their cross-sectional insights are drawn from a survey on the existing and planned uses of enterprise-wide stress testing conducted by the International Association of Credit Portfolio Managers (IACPM) and Oliver Wyman, with leading financial institutions around the world. Drawing upon survey results, Andy and Ilya describe the state of enterprise-wide stress testing, with a focus on how financial institutions are using this new capability. On the evolving role of enterprise-wide stress testing, they report a wide range of applications, including capital adequacy and planning, risk measurement and reporting, risk appetite statement, contingency planning, limit setting, financial planning and budgeting, strategic planning, capital allocation, credit portfolio structuring, performance measurement, pricing and origination strategy. In their chapter, special attention is paid to the various ways in which banks combine stress testing with economic capital measures. They also explore banks' aspirations for the next generation of stress testing. To achieve these aspirations, the authors highlight the areas banks must focus on: increased data and modelling granularity, improved data and modelling infrastructure, clear and effective governance, and robust and efficient processes.

In Chapter 3, Michel Araten traces the advancement of stress testing at banks from its precursors to its application following the imposition of regulatory stress tests, drawing from his experiences across four decades working at a number of banks. The chapter begins with an analysis of the origins of stress testing, as firms first sought ways to measure risk beyond the simple sensitivity analyses applied to a base-case set of assumptions underlying capital investment decisions. The application of simulated outcomes to probabilistic events led to capital modelling, which eventually helped the development of the concept of economic capital, providing banks with basic tools to assess risk-adjusted returns on capital. Michel uses a number of case examples to illustrate the earliest stress-testing approaches banks used to explore the robustness of their economic capital models and loss estimates. While Basel II provided the impetus for regulators to push banks with more formalised approaches for estimating regulatory capital, it was only after the financial crisis that stress testing became an important regulatory tool for measuring capital adequacy. Due to the need for banks to adequately demonstrate their capital resiliency under severely adverse scenarios, the use of stress-testing outcomes is likely to have a significant impact upon their portfolio management and capital planning. Impacts can be positive, as banks seek ways to better incorporate stress-testing results into their decision-making. However, the author raises the important issue whether or not the regulatory-driven stress-testing regime will result in banks using less imagination and creativity in their risk analyses, instead becoming simply an exercise in compliance.

After providing the foundation and context on CCAR, the next section of the book (Chapters 4–12) covers the implementation and practical aspects of CCAR and stress testing. This section begins with discussions on macroeconomic scenario design, followed by the coverage of data and systems, and the modelling and quantification of loss and revenue for various asset classes and risk types.

Given the central role macroeconomic scenarios play in CCAR and stress testing, we devote two chapters to discussions of scenario design, each with a different focus. In Chapter 4, Mark M. Zandi considers the appropriate design of the macroeconomic scenarios used for stress tests and some available tools and approaches. He begins with a discussion of the overarching criteria underpinning scenario design, illustrating them with the various modelling approaches used to implement scenarios. Specifically, Mark presents a methodology for constructing baseline, alternative and idiosyncratic scenarios, and for determining the associated probabilities of these scenarios. In Chapter 5, Kapo Yuen focuses on determining the severity of macroeconomic stress scenarios. He discusses the supervisory adverse scenario's severity, and provides a simple methodology to compare the severities of different adverse scenarios. The methodology enables measurement of the severity of a bank-specified scenario and comparison to that of the supervisory scenario. These measurements and comparisons can serve as useful indications of the credibility and plausibility of the stress scenario.

As highlighted in Chapter 2, financial institutions must invest in data and infrastructure to meet the challenges of supervisory stress tests and to reap the benefits of their business use. Despite its critical importance for stress testing and capital assessment, little literature addresses the subject. John P. Haley and Thomas Day address this void in Chapter 6. They begin by listing infrastructure challenges, and discuss some of the issues related to legacy data and remediation requirements. They then cover data governance issues, the data required to meet US stress-testing mandates and the basic elements of a sound data management infrastructure. Furthermore, using a practical example, John and Thomas look at some of the workflow challenges that may require banks to rethink existing business processes, which involves looking at how they plan new business actions over a forecast horizon. Last, they profile a stylised system integration for a large, complex BHC, and discuss how the new requirements will impact customers, concluding with some thoughts on the road ahead. While this chapter focuses on the data and technology implications of meeting the regulatory requirements, it also suggests that the most successful banks will be the ones that learn how to harness the insights gained from the CCAR work into better tools for their business use.

While data and technology represent some of the foundational aspects of CCAR, the quantification of loss and revenue, and the dynamic modelling of the evolution of the balance sheet and income statement, consume a large portion of the efforts involved with CCAR exercises. Subsequent chapters cover the topics of loss estimation for major asset classes (wholesale and retail) and major risk types (credit, market and operational). Chapters 7 and 8 cover stress testing for the wholesale portfolio. In Chapter 7, Jimmy Yang and Kenneth Chen present a multi-view framework for stress-testing commercial and industrial (C&I) portfolios. After discussing the unique characteristics of C&I portfolios and the resulting challenges for stress testing, they present their multi-view approach, which consists of a number of models with different degrees of granularity. The approach includes a top-down approach based upon modelling net charge-off, and a very granular, bottom-up method that involves stressing the inputs of an internal rating model. They also present methods with different levels of segmentation, such as modelling credit migration and changes in probability of default (PD). Besides PD, the authors also discuss several commonly used methodologies to stress loss given default (LGD) and exposure at default (EAD). Jimmy and Kenneth also illustrate how various components can be combined to arrive at the recommended results, from both quantitative and qualitative perspectives, in order to properly assess and hedge model uncertainties. One notable aspect of this discussion is the translation of PD, LGD and EAD into the accounting metrics of net charge-off and Allowances for Loan and Lease Losses (ALLL).

In Chapter 8, Jun Chen covers the topic of stress testing CRE loans of the wholesale portfolio. He first provides a tutorial on the unique characteristics of CRE loans and how they differ by lender type (banks versus non-bank institutions). Jun then presents a coherent analytical framework for stress testing CRE loans, where a top-down macro view is connected with bottom-up, loan-level specifics to derive reliable loss estimates for CRE loans. The key element of the framework involves translating macroeconomic scenarios into key measures of CRE markets and the quantification of the default and loss rates, given the CRE market measures. Jun illustrates how the framework can work for income-producing as well as construction loans, and comments on the subject of model validation – suggesting appropriate context for, and ways to interpret, scenario-based model outputs.

After discussing wholesale portfolios, in Chapter 9, Soner Tunay and Rosa Català present a comprehensive and integrated framework for stress testing retail portfolios. Their framework has a number of key features. The framework is integrated, in that it captures the simultaneous interaction between loss drivers and the factors influencing the revenue-generation process. It also incorporates product-specific characteristics and bank internal policy variables, such as underwriting standards. The framework covers all retail products (mortgages, credit cards, car loans, etc) under the same macro scenario using the same methodology, and has bank-wide implementation. The framework also provides multi-period and lifetime product views, and captures the dynamic changes in a product's life and implications for revenue and loss realisations for each future point in time. Soner and Rosa describe how multiple divisions within the bank – risk, treasury, finance and business – collaborate to establish the framework. With buy-ins from all stakeholders, the framework can be applied in business applications to help inform budgeting and planning, sales targets, capital utilisation, etc.

Following the previous three chapters on stress testing loan portfolios, Chapter 10 explores the topic of market and counterparty credit risk of the trading book. Eduardo Canabarro discusses fundamental characteristics of market and counterparty risks, and how the stress tests of those risks can be designed and linked to the macroeconomic scenario in an integrated and coherent way. He then discusses the specific risk characteristics and vulnerabilities of commercial and investment banks' business models, and the stress tests most appropriate for them. Perhaps most importantly, Eduardo recommends specific improvements to the design of effective and realistic stress tests, especially for market and counterparty risks that emphasise the need for explicit consideration of the hedging and liquidity dynamics of trading portfolios, systematic reverse stress testing for identification of market risk vulnerabilities in complex trading portfolios and the simulation of dynamic hedging costs of credit valuation adjustments (CVAs).

In Chapter 11, Yakov Lantsman, Sabeth Siddique and Yan Shi introduce readers to operational risk, its evolution and stress testing. They provide a systematic overview of supervisory and bank idiosyncratic scenario structures and their implications for operational risk. Yakov, Sabeth and Yan then discuss the general approach to modelling operational risk, especially within the context of Basel II, and explain why CCAR requirements are different. Their methodological focus highlights linking both operational loss frequency and severity to macroeconomic scenarios, and how frequency and severity estimates can be aggregated to produce final operational loss estimates. In addition to the methodology discussions, the authors also provide advice on operational risk model capital buffers, reporting and effective challenge of models.

While stress testing primarily concerns loss (the main focus of the previous five chapters), projecting revenue conditioning on macroeconomic scenarios is also an integral piece of the CCAR process. Chapter 12 therefore covers the modelling of pre-provision net revenue (PPNR), which represents a large number of disparate income statement items, ranging from interest income, interest expenses, compensation expenses, trading revenue and expenses related to operational risk. PPNR spans virtually every aspect of a financial institution, and the items can be disjoint, in that available data, statistical properties and sensitivity to macroeconomic conditions can vary significantly. In this chapter, Amnon Levy discusses various quantitative approaches for linking macroeconomic scenarios with PPNR items. The approaches range in granularity, and depend upon the availability and quality of historical data, statistical properties of the line item, business use and model consistency across balance-sheet and income statement items. He discusses both quantitative granular approaches and top-down industry peer approaches to relating PPNR items with macroeconomic variables, before commenting on the applications of the models and consideration for an organisation's strategic plans and incorporating expert judgement. Relative to loss estimation, quantification of PPNR is a new field, and Amnon provides an assessment of the evolution of modelling approaches into the future.

As seen in the previous chapters, the implementation of CCAR and stress testing is a large, complicated undertaking that requires data, systems and modelling resources and efforts by multiple business units. The complexity and integrity of the process calls for rigorous and appropriate governance and control, the subject of Chapter 13. David Palmer and Paul Sternhagen present the key elements of governance over a capital adequacy process (CAP): strong board and senior management oversight, evaluation of capital goals; assessment of the appropriateness of stress scenarios considered; regular review of any limitations and uncertainties in all aspects of the CAP; and approval of capital decisions. Furthermore, David and Paul outline the sound internal controls that help govern an institution's CAP and help to ensure CAP integrity. These controls cover policies and procedures for change controls, model validation and independent review, comprehensive documentation and review by internal audit.

In Chapter 14, Dan Ryan and Pranjal Shukla provide an overview and comparison of the different capital management frameworks that exist within large banks, in addition to CCAR. The chapter can be considered a synthesis of the various aspects covered in the previous chapters. After presenting the evolution of capital management practices and related capital management initiatives, Dan and Pranjal offer a detailed comparison from two different lenses: modelling approaches, and governance and processes. They then describe how to leverage these different capital management practices and initiatives in an integrated manner for different capital management applications. The chapter ends with some insights on how banks should implement a target-state, comprehensive capital management framework that encompasses all of these initiatives, including CCAR.

As mentioned earlier, CCAR's significant impact is also being felt outside the US, with other regulators looking to the experiences and results of the Federal Reserve in developing their own capital adequacy assessment and stress-testing regimes. Chapter 15, by Piers Haben, Caroline Liesegang and Mario Quagliariello, contrasts the EU and the US experiences and attempts to disentangle why the two stress tests have been perceived so differently by respective market participants. The authors explain the important differences along the following dimensions: governance, scope, severity of the stressed scenario, methodology, outcome and disclosure. Their explanations increase our understanding and appreciation of the significant challenges that European regulators and banks face in designing and executing stress-testing programmes. Their insights are especially valuable to those non-US regulators in the process of designing their own capital and stress-testing regimes. The chapter also suggests possible options for future system-wide stress tests on a global basis, and contemplates the feasibility of a global stress test, at least for systemic institutions.

We close the book with a few summarising observations. CCAR has the potential to profoundly impact how banks conduct their capital adequacy assessment and planning, as well as their risk management processes. As a number of contributors have highlighted throughout this book, banks can (and should) use the impetus and opportunity of CCAR and stress testing to strengthen and improve their data, IT and system infrastructure, modelling, and governance and control for applications beyond regulatory compliance. However, it is also important to note that a regulatory-driven programme such as CCAR could contribute to creating a model and process monoculture and group-think across banks, which contradicts stress testing's spirit of assessing the unexpected and blind spots. How banks and regulators respond to these opportunities and challenges is a process that is still unfolding, just as CCAR has been evolving (and will continue to do so). Thus, it is important to note that the objective of this book is not to provide definitive explanations for everything related to CCAR. I hope the collective efforts by the contributing authors, while providing knowledge and sharing experiences, help initiate much-needed discussions and debates on all these topics, and provide ideas and insights for further thought. I trust the reader will find the ideas within this book informative, insightful and constructive.

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1 See Ben S. Bernanke, 2013, "Stress Testing Banks: What Have We Learned?", available at http://www.federalreserve.gov/newsevents/speech/bernanke20130408a.htm.

2 See Bank of England, 2013, "A Framework for Stress Testing the UK Banking System", discussion paper, October, available at http://www.bankofengland.co.uk/publications/Pages/news/2013/116.aspx.

3 See European Central Bank announcement: http://www.ecb.europa.eu/press/pr/date/2013/html/pr131023.en.html.

4 As indicated in individual chapters, their perspectives may not necessarily reflect those of authors' employers.

1

CCAR and Stress Testing as Complementary Supervisory Tools

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The financial crisis of 2007–09 highlighted a number of deficiencies in risk measurement and management practices, and in the financial resiliency of large systemically important financial institutions (SIFIs). Of particular importance was the lack of attention that had been paid to low-probability, high-impact events that could strain a firm's capital adequacy, test its ongoing viability and quickly spread to other financial institutions. Indeed, the continuation of capital distributions at many large bank holding companies (BHCs) well after it became apparent that there was substantial deterioration in the operating environment highlights the extent to which the supervisors and management of these companies underestimated the effect that stressed conditions could have on BHCs' financial soundness. In short, the crisis made clear the need for more robust supervisory and internal capital adequacy assessment processes at BHCs that incorporate a comprehensive, forward-looking assessment of capital adequacy under a variety of stressful scenarios, as well as the need for better firm-wide risk identification and measurement practices to support this analysis.

The annual stress tests conducted by the Federal Reserve (supervisory stress test) and the Comprehensive Capital Analysis and Review (CCAR) were designed as complementary programmes to strengthen both supervisory assessments of capital adequacy and the processes through which large, complex BHCs internally assess their capital needs. These programmes focus on BHCs' ability to absorb substantial unexpected losses while also experiencing significant declines in revenue, and to continue to function as credit intermediaries in a highly stressful environment. By ensuring that the largest BHCs each have sufficient capital to withstand significant stress and continue to operate, these programmes can also help the Federal Reserve meet its macroprudential supervisory objectives of ensuring that the financial system as a whole can continue to function under adverse conditions. Greater confidence in the largest BHCs' capacity to withstand stress and continue to operate and lend may well mitigate the extent of an economic downturn.

Supervisory stress tests provide the Federal Reserve with a concurrent, forward-looking assessment of capital adequacy across large, complex BHCs using a common set of scenarios, models and assumptions to support comparability. CCAR is a broader supervisory programme that includes supervisory stress testing, but also assesses BHCs' own practices for determining capital needs, including their practices around risk measurement and management, and capital planning and decision-making, as well as internal controls and governance around these practices. Together, these two programmes allow supervisors to move beyond the more traditional static analysis of capital ratios and to conduct a forward-looking evaluation of capital adequacy that incorporates both quantitative analysis and qualitative reviews of large BHCs' capital planning and positions.

The remainder of this chapter is organised as follows. First, we will briefly describe the evolution of stress-testing and related supervisory capital assessment programmes since the Supervisory Capital Assessment Program (SCAP) in 2009. Second, we will discuss key features of, and considerations for, supervisory stress tests. Third, we will briefly examine how supervisors assess BHC stress tests and capital planning in CCAR.[1] Fourth, we will focus on the role of public disclosure, a key feature of supervisory stress tests and CCAR. Finally, we conclude the chapter with some additional thoughts about the role of stress testing in CCAR.

CCAR AND STRESS TESTING: HOW DID WE GET HERE?

SCAP – the beginning

Although both supervisors and financial institutions conducted various forms of stress testing prior to the crisis, the genesis of the supervisory stress tests and CCAR dates back to early 2009, when supervisors conducted simultaneous stress tests of the 19 largest US BHCs for SCAP in the midst of the financial crisis. At the time, the 19 BHCs faced unprecedented deterioration in economic and financial market conditions, and the medium-term outlook remained highly uncertain. Investor confidence in the financial health of the banking system was low, with negative sentiment being exacerbated by the uncertain outlook. Concerns about the fundamental value of loans and securities held on the BHCs' balance sheets, and the effect of market illiquidity and volatility on asset valuations, led to widespread uncertainty about the solvency of large BHCs as a group.

The SCAP sought to address this uncertainty by quantifying the potential effect on capital of further deterioration in the economic environment, to a level that was unprecedented post-World War II. Specifically, the SCAP stress test assessed potential losses and capital shortfalls at the 19 large BHCs under a uniform scenario that was by design even more severe than the expected outcome at that time. The design of the SCAP stress test partly reflects the view that ensuring that large BHCs have sufficient capital to weather a worse-than-expected outcome could mitigate the propagation of adverse shocks to the financial markets and the economy as a whole. The SCAP used a wide range of inputs, including BHCs' own estimates, supervisory model outputs, data collected from banks and supervisory judgement, to produce estimates of losses, revenues and capital levels.[2]

Importantly, the SCAP assessed whether a BHC had sufficient capital to absorb losses and to continue to operate as a financial intermediary by requiring BHCs to meet a post-stress Tier 1 common equity ratio of 4% and a Tier 1 risk-based capital ratio of 6%.[3] BHCs that fell below this capital ratio target were given one month to develop a detailed capital plan and six months to raise the necessary capital to meet the target. In addition, the US Treasury Department provided a capital backstop in the event any of the 19 BHCs that were found to be in need of capital (that is, had post-stress Tier 1 common equity ratios below 4% or post-stress Tier 1 risk-based capital ratios below 6%) under the SCAP were unable to raise that equity in private markets. Notably, while 10 out of 19 BHCs that participated in the SCAP failed to meet the post-stress capital target, almost all those with projected capital shortfalls were able to privately raise sufficient equity after the public release of the SCAP results.[4]

By most assessments, the SCAP was a significant contributor to the stabilisation of the financial system.[5] While the Treasury backstop was undoubtedly an important element in the SCAP's success, the credibility of the stress test and the public disclosure of its results were also significant contributing factors. The stress tests conducted under the SCAP tested the capital adequacy of the 19 BHCs in a meaningful way – using a severe scenario that yielded estimates of significant potential losses and declining revenues, and a substantial reduction in capital – that supported the perceived credibility of the exercise. In addition, supervisors released bank-by-bank results, the first time such a public disclosure of supervisory information had been made. The public disclosure, which included projected losses by asset type and capital shortfalls relative to the post-stress target, reduced the information asymmetry between the market participants and BHCs. Overall, the combination of the widely perceived credibility of the SCAP stress test and the public disclosure of the results helped reduce uncertainty about the financial health of the large BHCs and restore confidence in the US banking system.

CCAR and Dodd–Frank Act stress tests

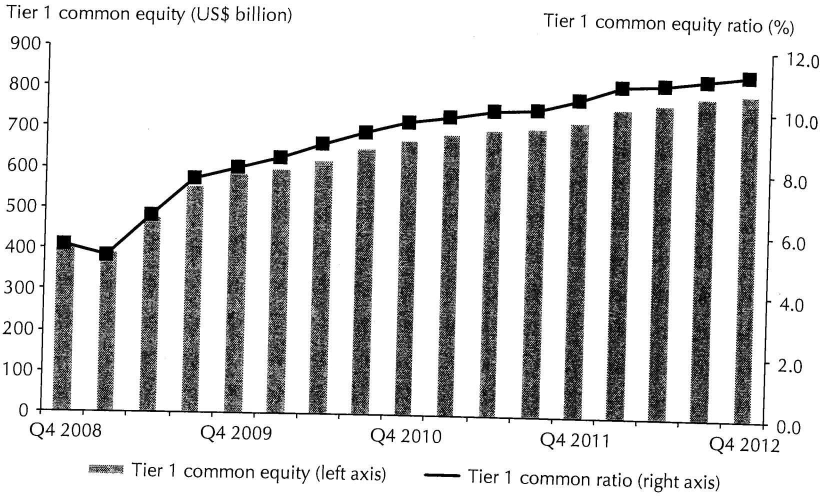
Building on the lessons learned from the SCAP, the Federal Reserve initiated CCAR in late 2010 to assess the capital adequacy and the internal capital planning processes of large, complex BHCs, and to explicitly and permanently incorporate the forward-looking capital assessment provided by stress testing into the supervisory evaluation of capital adequacy. Initially, the CCAR programme covered the same 19 BHCs that participated in the SCAP.[6] In November 2011, the Board of Governors issued a rule that required all US BHCs with total consolidated assets of US$50 billion or more to submit annual capital plans to the Federal Reserve and to allow the Federal Reserve to assess whether the plans are supported by robust, forward-looking capital planning processes, and whether they have sufficient capital to continue operations throughout times of economic and financial stress.[7] Subsequently BHCs that met the US$50 billion asset threshold of the rule, but had not been part of the SCAP, also submitted their capital plans under the capital plan rule. However, their capital plans were assessed under the Capital Plan Review (CapPR), not CCAR, consistent with the phasing in of CCAR expectations. Beginning in 2014, all 30 BHCs with total consolidated assets greater than US$50 billion will be part of CCAR.

In addition, the Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010 (DFA) required the Federal Reserve to conduct annual supervisory stress tests under three scenarios – baseline, adverse and severely adverse – and to publicly disclose the results of the stress tests. While the frequency, timing and supervisory expectations vary depending on each company's size and complexity, the DFA also required all federally regulated financial companies with US$10 billion or more in total consolidated assets to conduct their own internal stress tests each year, and to publicly disclose the results of these internal stress tests under the DFA severely adverse scenario.[8]

Under CCAR, the post-stress capital ratios are calculated using the capital actions[9] in the BHCs' capital plans, while supervisory stress tests conducted under the DFA use stylised assumptions about capital actions that are required in the stress testing rule to calculate the post-stress capital ratios. The Federal Reserve's DFA stress-test rule assumes that no future capital action that may be subject to future adjustment, market conditions or other regulatory approvals will be reflected in a company's projected regulatory capital. As a result, supervisory stress tests conducted under the DFA incorporate a standardised set of capital action assumptions: continuation of the previous year's level of dividends, no repurchases or issuances.[10] By comparison, post-stress capital ratios for CCAR incorporate BHCs' planned capital actions over the nine-quarter planning horizon under their baseline scenario. The inclusion of the baseline planned capital actions tests whether the BHCs would remain above the minimum post-stress supervisory targets even if they maintained their planned capital actions and the stressful conditions were realised.

Public disclosure continues to be an important feature of stress testing and of CCAR. In spring 2013, the Federal Reserve published the results of its supervisory stress tests under the severely adverse scenario conducted under the DFA for 18 BHCs.[11] Around that time, the same 18 BHCs disclosed the results of their stress tests conducted under the DFA severely adverse scenario. In addition, the Federal Reserve published the post-stress capital ratios under CCAR, and for the first time disclosed the decision (and the basis for the decision:

Figure 1.1 Aggregate Tier 1 common equity ratio for 18 BHCs that participated in CCAR between 2008 and 2012



Source: Federal Reserve

Note: Aggregate capital ratio for 18 participating BHCs, based on Y-9C filings. The Tier 1 common ratio in the fourth quarter of 2008 includes the Tier 1 common capital and risk-weighted assets for Ally Financial Inc. as of the first quarter of 2009, as Ally did not file a Y-9C report with the Federal Reserve in the fourth quarter of 2008.

qualitative or quantitative) to object or not object to a BHC's capital plan.[12]

Since the SCAP, stress testing and supervisory programmes such as CCAR have been credited with promoting significant capital accretion among large, complex BHCs in the US. Notably, the aggregate Tier 1 common equity ratio of the 18 BHCs that participated in CCAR through 2013 has more than doubled in the nearly five years since year-end 2008, from 5.6% to 11.3% – a net gain of about US$400 billion of Tier 1 common equity in absolute terms (see Figure 1.1). In addition, CCAR is leading to improvements in risk measurement and capital planning practices across the firms.

KEY FEATURES AND CONSIDERATIONS FOR SUPERVISORY STRESS TESTS

The Federal Reserve conducts concurrent supervisory stress tests for all large BHCs, based on the same set of scenarios and models, providing a comparable view of capital adequacy across the large

BHCs. The concurrent nature of the supervisory stress tests and CCAR allows the Federal Reserve to take a cross-BHC perspective and an aggregate industry perspective across time in its assessment, serving both microprudential and macroprudential supervisory objectives. While some of the key elements of the supervisory stress tests – including a common set of scenarios, concurrent stress testing of a large share of the US banking system and public disclosure of bank-by-bank results – have not changed since the SCAP, there has been significant evolution in the models used to support supervisory stress tests, in large part due to new data collections that support supervisory loss and revenue estimation techniques.

Supervisory stress tests have begun to use extensive data collected at regular intervals from the BHCs through regulatory reports. While there will always be information asymmetry between the regulators and the BHCs, the data collection that was formalised in late 2011 helped fill the information gap, and enhance supervisors' understanding of BHCs' portfolio risks and the sensitivity of revenues to stress scenarios. In addition, the data collection created strong incentives for large BHCs to develop internal processes that allow for better aggregation across different systems and to provide very detailed data about their borrowers, positions and sources of revenue. A positive by-product of the supervisory stress tests has been enhancements in the data BHCs themselves have available for use in their risk measurement and capital planning.

In part due to the detailed data that are now available, supervisory models have become both more independent and more sophisticated, allowing the Federal Reserve to project revenue, expenses and losses using the data provided by the BHCs, without relying on BHC estimates. In contrast, as mentioned above, the final supervisory estimates produced in SCAP represented a triangulation of a range of inputs, including BHCs' own estimates, supervisory model outputs, data collected from banks and supervisory judgement. Supervisory models based on more granular, BHC-reported data have allowed supervisors to better account for the underlying characteristics of each BHC's borrowers and portfolios, and to better incorporate non-linearity in loss or revenue estimates under stress. The increasing independence of the supervisory models not only further enhances the comparability of results across BHCs, but also supports the credibility of the results.

While the supervisory stress scenarios contain severe stresses that would likely affect BHCs broadly, they are not meant to provide an all-encompassing assessment of the potential stress events or risks each BHC faces. Rather, supervisory scenarios are designed to identify and stress vulnerabilities to common risk factors across BHCs, even if these scenarios may not necessarily be the most severe scenarios for each individual BHC. Supervisory scenarios designed to capture common risks across BHCs should be viewed as a complement to BHC-designed scenarios that explicitly consider BHCs' idiosyncratic risks and vulnerabilities, and which are reviewed and assessed by supervisors during CCAR.

Finally, supervisory stress tests and the models used to support stress testing will likely evolve further over time as BHCs' risk characteristics and business models evolve, the relationship between scenario variables and BHC performance shifts, and the economic and market environment in which BHCs operate changes. In order for supervisory stress tests to remain focused on key vulnerabilities facing the banking system, supervisors will need to update their understanding of the potential risks embedded in new products and businesses, and how emerging risks may affect BHCs' portfolios and businesses – particularly under stress scenarios – through broad supervisory efforts and ongoing research, and incorporate those risks into supervisory stress tests.

ASSESSMENT OF BHC STRESS TESTS AND CAPITAL PLANNING IN CCAR

CCAR is a comprehensive supervisory programme that assesses – quantitatively and qualitatively – both BHCs' capital adequacy under stressful scenarios and their capital planning processes. BHCs' internal stress tests, based on the scenarios developed for those stress tests, are key components of their capital planning processes, which should reflect the BHC's views of their own risks and capital needs. In addition to its use as a tool for the supervisory evaluation of capital adequacy at BHCs, other key objectives of CCAR include: promoting better identification, measurement and management of risk at the largest BHCs; fostering greater consideration among boards of directors and senior management at BHCs of potential "tail risk" when assessing their capital needs; and enhancing the corporate governance around BHCs' internal assessments of capital needs and capital distribution decision-making. While these objectives are similar to more traditional supervision programme elements, they differ in their focus on forward-looking stress analysis in the capital planning process. For example, with CCAR, supervisors expect the BHCs to identify, measure and capture their risk exposures, and also consider how risks may emerge and grow under stress. In addition, supervisors also expect key decision-makers within each BHC to consider a variety of stress scenarios in the analysis supporting their assessments of capital needs and capital distribution decision-making.

While supervisory and company-run stress tests provide the forward-looking quantitative assessment of capital adequacy under stress scenarios, qualitative assessments focus on the BHC's processes around internal capital planning, including BHCs' own scenarios. For CCAR, each BHC must submit internal stress-test results based on the baseline and stress scenarios it develops (BHC scenarios), in addition to the three supervisory scenarios. These BHC scenarios are expected to capture BHC-specific, idiosyncratic risks in addition to a broad macroeconomic downturn that characterises the supervisory scenarios. The qualitative assessment covers a broad array of supervisory expectations around risk identification, risk measurement and risk management practices that BHCs use to support their capital planning and internal stress tests, including practices used to estimate stressed net revenue and stressed losses, and the governance and controls around these practices.[13]

Supervisors expect that that each BHC's internal stress-testing framework and capital planning process considers how it would fare under a range of stress scenarios, including those defined by bank-specific idiosyncratic elements. While robust stress-testing models should have some basic features, such as sensitivity to macroeconomic conditions and underlying risk characteristics in BHCs' portfolios, there are many possible ways to model revenues and losses under stress scenarios. As noted by a number of observers, to avoid the danger of a "model monoculture,"[14] it is important to ensure that BHCs develop internal models that best capture their own risks, rather than relying on models that closely mirror supervisory models.

PUBLIC DISCLOSURE OF RESULTS AND METHODOLOGIES

As noted earlier, the Federal Reserve first published the bank-by-bank results of its stress tests following the SCAP and since then has continued to expand public disclosure around supervisory stress tests and CCAR with the release of more detailed stress-test results and views on BHCs' capital planning processes. The public disclosure provides significant information about the financial health of large BHCs, and improves the transparency of supervisory assessments of the capital adequacy of these firms.

The Federal Reserve has also disclosed an overview of the models used to conduct supervisory stress tests. The overview of supervisory models published in the spring of 2012 and 2013 was comprehensive, but stopped short of revealing the exact specifications of the models or parameter estimates in order to reduce the risk of model convergence.[15] Many in the industry have called for greater transparency into the Federal Reserve's models, and have criticised the supervisory stress test for being a "black box." Indeed, in evaluating the optimal level of model disclosure, supervisors balanced the need for supervisory transparency against a potential for negative unintended consequences, such as model convergence or a shift in business activity to areas where risks were not as well captured by the stress-testing models. The public disclosure of the qualitative assessment of a BHC's capital plan, which also covers its risk identification, stress testing and capital planning processes, should shift the focus away from supervisory models and estimates over time, and help mitigate concerns about model convergence.

However, some observers continue to express concerns about the extent of stress test and CCAR disclosure – particularly as the stress testing has become an annual exercise – arguing that the bank-level disclosure may damage market discipline. They have argued, for example, that the bank-by-bank disclosure of results may diminish the usefulness of market prices if it creates a disincentive for investors to obtain and produce private information about the banks.[16] They have also argued that bank-level disclosures could introduce an incentive for banks to re-allocate their portfolios solely to avoid "failing" supervisory stress tests and receiving an objection to their capital plan.

Given the widely held view among supervisors and most third-party observers that the public disclosure of stress-testing results enhances available information and supports market discipline, it will continue and is perhaps even likely to be expanded over time. This disclosure provides more information for investors and other market participants than was previously available. Disclosure of bank-by-bank supervisory stress-test results, combined with disclosure by each BHC of its results under the same severely adverse scenario, also provides an unprecedented comparative view of the largest BHCs' financial strength across the banking system. It is important to note, however, that while providing valuable information to market participants, supervisory stress-testing results that are disclosed annually are not meant to be a substitute for market prices or other privately-generated information about the strength and performance of BHCs that are available at a much higher frequency. Rather, the information this disclosure provides should be seen as complementary to these other sources. Given the breadth of information market participants typically use to analyse large BHCs, it is difficult to envision that the generation of other information critical for market participants in conducting their business each day would be reduced simply because of the annual disclosure of stress-testing results.

In addition, it is unclear how less disclosure would help reduce, in any meaningful way, a BHC's incentive to reallocate assets in response to a regulatory framework that is being used to assess its capital adequacy. Indeed, given the reality of minimum regulatory capital requirements, such incentives have always existed and would exist irrespective of public disclosure of stress-test results. Concerns about the potential reallocation of portfolios with no corresponding reduction in underlying risks are addressed within the context of ongoing supervision, and supervisory assessments in CCAR of BHC scenarios, models and the comprehensiveness of BHCs' risk capture in their internal capital planning processes. Finally, disclosing aggregate but not bank-specific results could be viewed as masking important information about specific banks, undermining the credibility of the supervisory stress tests and potentially creating or exacerbating market uncertainties.

It is also important to note that publishing stress-testing information promotes high-quality supervision, as the disclosure serves as a commitment device and holds supervisors accountable. In the SCAP, the disclosure of capital shortfalls clearly held supervisors accountable for producing sound stress-test results and following through to ensure banks raised the necessary capital. The annual CCAR disclosure re-enforces supervisory accountability for similar reasons. The minimum supervisory post-stress capital targets are set clearly – BHCs must meet all minimum regulatory capital ratios that will be applicable over the stress-test planning horizon,[17] and a 5% Tier 1 common equity ratio, all post-stress. The implications of falling below those targets or of having capital planning practices that do not meet supervisory expectations are also clear.

Perhaps rather than limiting disclosure, the more relevant response to concerns about supervisory disclosure is to ensure that scenarios and supervisory models do not remain static over time, and to balance the need for transparency of supervisory models against the need to create an incentive for banks to create their own models and to manage appropriately their portfolio risks. For these reasons, the Federal Reserve places additional focus on BHCs' internal processes for stress testing and capital planning, publicly noting the instances where capital plans were objected to for qualitative reasons. The disclosure of supervisory stress tests, qualitative assessment of BHCs' capital planning process and the BHCs' disclosure of their own stress tests should collectively help ease information asymmetry and reduce the potential for creating negative incentives.

CONCLUSION

Stress testing and the related supervisory expectations for capital planning have fundamentally changed the way the capital adequacy of large, complex BHCs are assessed by both supervisors and the BHCs. BHCs now consider post-stress capital ratios, in addition to current capital ratios, when making decisions around capital allocation and capital actions. As a result, many view CCAR as an alternative measure of a capital buffer above the regulatory minimum, one that in some cases may be more binding than the buffers that already exist in point-in-time regulatory capital requirements.

Based on this view, some have argued for full transparency and greater consistency over time, both in supervisory scenarios and supervisory models used to support stress testing, and CCAR to provide greater certainty of the outcome. While some consistency over time may be desirable, moving toward a more formulaic or rule-based approach that remains mostly unchanged over time would undermine the main strength of stress testing – namely, the flexibility to adapt over time to shifting economic environments, business models and products, and risk-taking behaviours. As a result, stress tests should best be viewed as a complement to, and not a substitute for, regulatory capital requirements that assess BHCs' capital adequacy at a given point in time. Given the inherent uncertainty about the environment in which BHCs operate, stress testing should also incorporate such uncertainty.

In the near future and as a result of DFA, regulatory changes will expand the scope of stress testing in the Federal Reserve's supervision of large financial institutions. In addition to large BHCs, stress testing will be used to assess the capital adequacy of non-bank SIFIs with business models and risk profiles that are materially different from BHCs. Under the proposed rule for large foreign banking organisations operating in the US, stress testing would also expand to US intermediate holding companies.[18] The expansion of the universe of companies that are subject to stress testing will present new challenges and opportunities to test the strength of key participants in the financial system under stress.

Over time, the Federal Reserve's stress-testing and CCAR programmes will likely continue to evolve along with the economic conditions and the risk profiles and business practices of large financial institutions. Nevertheless, forward-looking assessments of capital adequacy, supported by strong risk measurement and management, stress testing, and internal controls and governance processes needed to ensure the institution's integrity, will likely remain the core element of supervisory expectations around capital planning.

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1 For details on supervisory expectations in CCAR, see Board of Governors of the Federal Reserve System, 2013, "Capital Planning at Large Bank Holding Companies: Supervisory Expectations and Range of Current Practices", August; Board of Governors of the Federal Reserve System, 2013, "Comprehensive Capital Analysis and Review 2014: Summary Instructions and Guidance", November.

2 See Board of Governors of the Federal Reserve System, 2009, "The Supervisory Capit Assessment Program: Design and Implementation", May.

3 The Tier 1 common capital ratio is defined as Tier 1 capital less the non-common elements o Tier 1 capital, including perpetual preferred stock and related surplus, minority interest i subsidiaries, trust-preferred securities and mandatory convertible preferred securitie divided by risk-weighted assets.

4 See Board of Governors of the Federal Reserve System, 2009, press release, November 9.

5 See B. Hirtle, T. Schuermann and K. Stiroh, 2009, "Macroprudential Supervision of Financia Institutions: Lessons from the SCAP", Federal Reserve Bank of New York, Staff Report No 409; S. Peristiani, D. Morgan and V. Savino, 2010, "The Information Value of Stress Test and Bank Opacity", Federal Reserve of Bank of New York, Staff Report No. 460.

6 One of the 19 BHCs that participated in the SCAP, MetLife Inc, deregistered as a BHC i 2012 by selling its bank subsidiary, and is no longer part of CCAR.

7 See Board of Governors of the Federal Reserve System, 2011, "Capital Plans", Final Rule, 7 Federal Register, No. 231, 74631–74648.

8 BHCs with US$50 billion or more in consolidated assets must conduct another set of stres tests (mid-year stress tests) each year using three sets of scenarios they develop, and publis the results (see Board of Governors of the Federal Reserve System 2012, "Supervisory an Company-run Stress Test Requirements for Covered Companies", Final Rule.77 Federa Register, No. 198, 62378–62396).

9 The capital plan and DFA stress-test rules define a capital action as "any issuance of a deb or equity capital instrument, capital distribution, and any similar actions that the Federa Reserve determines could impact a large bank holding company's consolidated capital." A capital distribution includes dividend payments or share repurchases.

10 However, common stock issuance associated with expensed employee compensation is incorporated in the analysis.

11 See Board of Governors of the Federal Reserve System, 2013, "Dodd–Frank Act Stress Test 2013: Supervisory Stress Test Methodology and Results", March.

12 See Board of Governors of the Federal Reserve System, 2013, "Comprehensive Capital Analysis and Review 2013: Assessment Framework and Results", March.

13 Key elements of this assessment are discussed in detail in Federal Reserve System, 2013, "Capital Planning at Large Bank Holding Companies: Supervisory Expectations and Range of Current Practice", August, available at www.federalreserve.gov/newsevents/press/bcreg/20130819a.htm.

14 See B. Bernanke, 2013, "Stress Testing Banks: What Have We Learned?", speech at Maintaining Financial Stability: Holding a Tiger by the Tail, Federal Reserve Bank of Atlanta, Georgia; T. Schuermann, 2013, "The Fed's Stress Tests Add Risk to the Financial System", *Wall Street Journal*, March 19.

15 See Board of Governors of the Federal Reserve System, 2013, "Comprehensive Capital Analysis and Review 2012: Methodology and Results for Stress Scenario Projections"; Board of Governors of the Federal Reserve System, 2013, "Dodd–Frank Act Stress Test 2013 Supervisory Stress Test Methodology and Results".

16 See I. Goldstein and H. Sapra, 2013, "Should Banks' Stress Test Results be Disclosed? An Analysis of the Costs and Benefits", working paper; T. Schuermann, 2013, "Stress Testing Banks", Wharton Financial Institutions Center.

17 Starting with CCAR 2014, both supervisory and company-run stress-test projections must reflect revised capital rules to be effective for the largest BHCs on January 1, 2014, with required phasing-in of various components.

18 See Board of Governors of the Federal Reserve System, 2012, "Proposed Rule on Enhanced Prudential Standards and Early Remediation Requirements for Foreign Banking Organizations and Foreign Nonbank Financial Companies".

2

Financial Institution Perspectives on the Evolving Role of Enterprise-wide Stress Testing

Andy McGee and Ilya Khaykin

Oliver Wyman

Enterprise-wide stress testing,[1] as a formal discipline for risk and capital management, was born out of the financial crisis. Stress tests had previously been carried out for certain types of risk or for specific portfolios, but rarely for all the risks faced by an entire enterprise. For example, market risk stress testing was widely adopted in the 1990s to supplement value-at-risk (VaR) measures, whose calculation tends to underestimate extreme losses. While these narrow stress tests were useful for managing specific risks or portfolios, they shed little light on the overall effect that a "stress event" would have on an institution.

During the 2000s, some institutions began enterprise-wide stress testing, typically estimating the losses from a single risk factor, such as an equity price crash or a housing price decline. These stress tests tended to be *ad hoc*, with no systematic way of articulating the scenarios or estimating the consequent losses, and they focused more on earnings than on capital or solvency.

To assess their solvency position, or capital adequacy, banks instead relied on regulatory capital and economic capital. Regulatory capital has been the most important lens for capital adequacy. Provided that an institution's capital exceeded the regulated minimum, it was taken to be adequate, even although it might be inadequate to maintain solvency during a stressed period. Economic capital was developed in the 1990s to remedy some of the know shortcomings of regulatory capital, such as failing to count all ris and conflating materially different risks. By avoiding these potenti pitfalls, economic capital provided banks with a more effecti measure of relative risk and a better foundation for making busine decisions.

However, economic capital took a purely probabilistic view capital adequacy, aiming to answer the question, "How much capit is needed to ensure the institution remains economically solven except in a very extreme event?" This approach overlooked th underlying dynamics of bank failure – both the causes and th process of failing – and that the point at which creditors' confidenc is lost is more important, and usually comes sooner, than the point a which the bank can no longer pay its depositors.

During the financial crisis of 2007–08, many banks failed despit having capital well in excess of the regulatory minimum. The marke judged banks' solvency not by their current capital, but by the capital that would remain once losses were fully recognised. Banks realised that the salient questions were: "What will your capital levels be in year or two if this crisis continues?"; "Will the bank still be able t operate as a going concern?"; and "Will the bank need more capital?" Regulators also demanded answers to these questions, starting with the Supervisory Capital Assessment Program (SCAP) in the US in 2009, soon followed by similar exercises in other jurisdictions. This has all led to the structure of enterprise-wide stress testing now common at banking institutions.

Since 2009, stress testing has advanced rapidly to meet increasing regulatory demands for this new perspective on capital adequacy. In the US, it has become clear that stress testing will continue to be a preferred instrument for prudential regulation. It is embedded in legislation through the Dodd–Frank Act (DFA), regulators continue to increase their expectations in the annual Comprehensive Capital Analysis and Review (CCAR) process and the implications of a failure to achieve a satisfactory outcome have been critical for senior management at financial institutions. As a result, it is necessary that risk management tools and practices evolve to support stress testing. Because stress testing requires a projection of losses conditional on a specific macroeconomic scenario, it has required most banks to develop new methodologies, models and infrastructure beyond those used to calculate economic capital. This has been the main focus of risk management at financial institutions in the years since the financial crisis.

This chapter will therefore discuss the state of enterprise-wide stress testing, with a focus on how financial institutions are using this new capability. It will begin by reporting on the role of enterprise-wide stress testing, especially the use banks make of it and the ways they combine it with measures of economic capital, before banks' aspirations for the next generation of stress testing capabilities are explored. Finally, the chapter will discuss some of the challenges banks face in taking their stress-testing capabilities to the next level.

In 2013, the International Association of Credit Portfolio Managers (IACPM)[2] and Oliver Wyman conducted a joint survey with leading banks around the world that focused on the existing and planned uses of enterprise-wide stress testing. The participants included 55 of the world's largest banks and insurance companies across North America, Europe and Asia–Pacific. The survey involved 59 multiple choice and free-form questions (some of which had multiple sub-questions) on the scope and process of enterprise-wide stress testing, stress-testing applications as well as organisation and governance. Participants were asked not only about their current practice, but also their plans for stress testing in the future. Throughout this chapter, the terms "surveyed institutions" and "survey respondents" refers to this survey.

WHAT IS THE ROLE OF ENTERPRISE-WIDE STRESS TESTING?

The impetus for setting up enterprise-wide stress testing in most jurisdictions was a regulatory requirement around capital adequacy assessment. As a result, the early use of enterprise-wide stress testing was narrow, focusing on whether there was sufficient capital to survive a stress event and what capital actions, such as making dividend payments, were possible. However, financial institutions have since built up their stress-testing capabilities and explored ways of using it to meet broader risk management and business objectives – specifically, for which applications or decisions will stress testing be a key input or driver? Should risk appetite be articulated based upon tolerances in a stress environment? Should capital requirements from stress testing be used for performance management or loan pricing?

Banks have cited a number of reasons for incorporating enterprise-wide stress-testing results into a broader set of such ris and business applications.

- *Binding constraint:* Enterprise-wide stress-test results hav become the binding constraint for evaluating capital adequac and the key driver of dividend policy for many institutions.
- *Management attention:* Given its linkage to dividend payments, a well as the governance requirements demanded by regulators enterprise-wide stress testing has the attention of senior management and the board of directors.
- *Intuition:* Many users find enterprise-wide stress-test results t be more intuitive than other risk metrics because they ar presented in an accounting framework, similar to other externa communications regarding the institution's financial condition.
- *Transparency:* Because outcomes are linked to causal factors in enterprise-wide stress testing, such results are also more transparent and easier to understand than other risk metrics (such as economic capital).
- *Consistency:* The enterprise-wide stress-testing process usually "piggy-backs" the budgeting and planning process, which gives it a degree of consistency with the inputs and approaches accepted already in a well-established process.

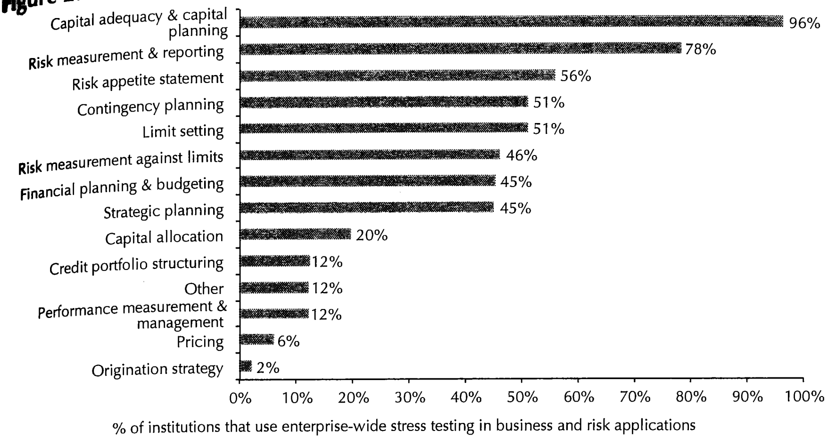
Applications of enterprise-wide stress testing

As can be seen in Figure 2.1, almost all surveyed institutions use enterprise-wide stress testing to measure capital adequacy. However, half or more also use it for risk reporting, risk appetite, limit setting and management, and various planning exercises (eg, financial, strategic, contingency).

Examples of such extended uses of enterprise-wide stress-testing results include the following.

- *Risk reporting:* Enterprise-wide stress-testing results are often used to report levels of risk in business activities – for example, by reporting the credit losses by portfolio in various stress scenarios would cause in specific portfolios, or by showing a business unit's contribution to the P&L in a stress scenario.
- *Strategic planning:* Enterprise-wide stress-testing results are increasingly integrated into business planning as institutions

Figure 2.1 Role of stress testing by business application



Source: IACPM/Oliver Wyman enterprise-wide stress testing survey

look to understand the impact of stress scenarios on alternative strategies, and especially on the ability to pay dividends.

- *Risk appetite:* Stress testing is increasingly being integrated into risk appetite, using tolerance for outcomes in a stress to set risk appetite and cascade it down to risk appetite/tolerance for individual products/businesses.
- *Limits:* Stress-testing expressions of risk appetite are often cascaded into limits at the enterprise level.

To a lesser extent, banks are also using enterprise-wide stress testing to inform capital allocation, credit portfolio structuring, performance measurement and management, pricing and origination strategy.

Balancing enterprise-wide stress testing and economic capital

Banks have traditionally used economic capital metrics for many core risk management applications. Stress testing has come to be in competition with economic capital for influence across these applications (see Panel 2.1 for a summary of the key characteristics of the two tools). As shown in Figure 2.2, the outcome is mixed, with enterprise-wide stress testing being used alongside economic capital in a subset of largely top-of-the-house applications, while economic capital remains the dominant risk metric in other applications, such as performance measurement and risk-based pricing, that require greater granularity and consistency in the risk metric applied acro the portfolio. As presented in Figure 2.2, less than 10% of institutio reported use of both economic capital and stress testing for thes applications.

PANEL 2.1 CHARACTERISTICS OF ENTERPRISE-WIDE STRESS TESTING AND ECONOMIC CAPITAL

Enterprise-wide stress testing

- accounting-based;
- considers the entire P&L, including revenues, losses and expenses;
- short- to medium-term forecast (eg, typically nine quarters in the US)
- reveals mechanics of how potential risks arise;
- loss level defined by a specific macroeconomic scenario, loosel linked to a probability (eg, "adverse"); and
- adverse loss typically not an insolvency event.

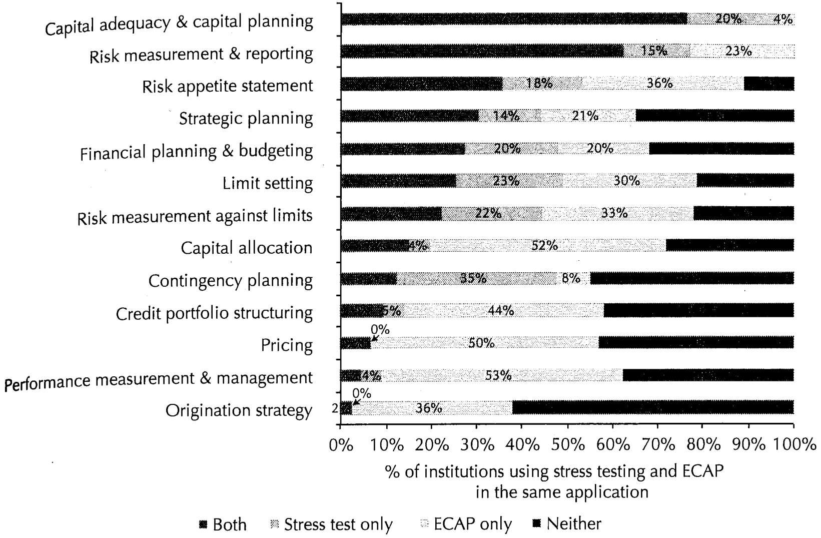
Economic capital

- value-based;
- one-year forecast (but often embeds changes in long-term value);
- loss level defined at a specific confidence level (ie, probabilistic) typically not linked to a specific macroeconomic scenario; and
- adverse loss typically an insolvency event.

Applications where economic capital and enterprise-wide stres testing are both used include risk reporting, risk appetite, limi setting and management, and strategic and financial planning. Ove half of the surveyed institutions that responded they use enterprise-wide stress testing in these applications also reported use o economic capital as a complementary measure. Having two perspectives on potential losses or capital consumption is useful, and ca also help to identify modelling errors. However, when enterprise-wide stress-testing results and economic capital suggest differen courses of action, banks must either reconcile the two perspectives to produce consistent answers or have a process for deciding which metric should guide decision-making.

For other applications, such as capital allocation, credit portfolio structuring, pricing performance management and origination strategy, economic capital is still the dominant risk metric. The use of stress testing in these areas faces theoretical and practical limitations (see Table 2.1 for a description of key challenges by application).

Figure 2.2 Use of stress testing and economic capital



Source: IACPM/Oliver Wyman enterprise-wide stress testing survey

The theoretical limitations arise from the fact that stress testing looks at the short-term accounting losses caused by stress scenarios and therefore fails to consistently capture risks that materialise over a longer horizon (such as asset/liability management, ALM, risks). This is inappropriate for applications that concern long-term value creation. Economic capital captures risks that may not materialise in financial statements over the short-time horizon of a stress test but which are required to understand the long-term value of a business or activity. Economic capital also facilitates comparisons across products and geographies because, given its calibration to a consistent confidence interval (such as 99.95%), each dollar of economic capital represents the same quantum of risk. By contrast, enterprise-wide stress-testing results are conditional on specific macroeconomic scenarios; different stress scenarios of equal probability could produce different losses across products/geographies.[3]

Additionally, in practice using stress tests for purposes that require comparisons between products, regions or customer segments is limited by the fact that stress testing does not specify losses at this level of granularity. Many uses of risk metrics require

Table 2.1 Applications of stress testing and their challenges

Application	**Description**	**Key challenges for use of enterprise-wide stress testing**
Capital adequacy	Ensuring institution maintains sufficient capital in line with risk appetite	• Managing between regulatory, stress testing-based and economic capital views of required capital and risk
Risk measurement and reporting	Communicating risk exposure across the organisation	
Risk appetite statement	Definition of the institution's high-level, risk-related objectives and constraints	
Contingency planning	Definition of contingency measures, such as capital raising and balance sheet reduction	• NA
Strategic planning	Medium-term planning of strategy and targets around business units, geographies and products	• Cultural shift in some cases to incorporate stress scenarios as a planning scenario • Organisational challenge to achieve finance buy-in on risk metrics
Financial planning and budgeting	Annual exercise to forecast revenues and expenses, and allocate budget across businesses	
Limit setting	Setting risk limits at business, product, portfolio and single-name level	• Scenario severity used for establishing limits and measuring risk against limits is difficult to define objectively
Risk measurement against limits	Measuring and monitoring usage of risk limits	
Capital allocation	Allocation of economic and regulatory capital at granular portfolio and business-line level	• Stress testing produces a narrow, scenario-conditional view of risk that may not be well suited to allocation and achieving consistency across exposures • Stress results are less accurate at granular levels at which capital allocation is needed for performance measurement and pricing purposes
Performance measurement and management	Measurement of risk/return of portfolios and business lines	
Pricing	Transaction-level pricing and decision support	
Credit portfolio structuring	Reshaping of credit portfolio based on risk metrics	• Stress results are less accurate at granular levels needed for transaction and portfolio-level decision-making
Origination strategy	Transaction level decision-making on loan origination	

ven position-level specificity and an ability to capture position-level drivers of risk. Economic capital can deliver this level of granularity but enterprise-wide stress testing cannot yet achieve this.

WHAT WILL BE THE FUTURE ROLE OF ENTERPRISE-WIDE STRESS TESTING?

The expectations for enterprise-wide stress testing at large US banks have increased each year in the CCAR and Capital Plan Review (CapPR) processes. The DFA stress-test (DFAST) rules have also required smaller banks to conduct enterprise-wide stress tests. Most of them will need to make rapid progress from their rudimentary stress-testing capabilities. In addition, European regulators have been demanding the increased use of stress tests, and Asian regulators are beginning to take the same position.

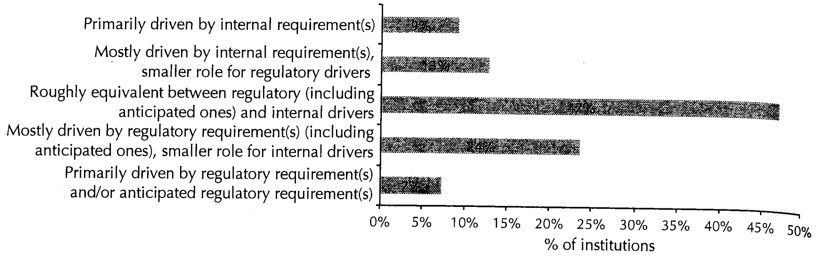
Beyond regulatory pressure, financial institutions consider enterprise-wide stress testing as a valuable management tool in its own right. About half of the surveyed institutions characterised their enterprise-wide stress testing as being driven equally by regulatory requirements and internal mandate.[4] Senior managers believe that the benefits of stress testing go beyond regulatory compliance.

Finally, financial institutions have another set of metrics (in addition to economic capital and regulatory capital) that are being produced, and have often made significant investment in stress-testing tools. They recognise the need for a coherent approach and framework for managing across these metrics, to ensure clarity within their organisation and in decision-making processes. It should be clear within an organisation how the different tools are applied to each decision, and how the answers provided should be used. In a world of multiple measures, this clarity is critical to making decisions in an efficient and effective manner.

For which applications are enterprise-wide stress testing being planned?

Most financial institutions plan to extend their use of enterprise-wide stress testing across the range of core risk management applications. Practically all surveyed institutions have aspirations to incorporate enterprise-wide stress testing into capital adequacy and capital planning (if not already doing so), and into risk reporting and risk appetite statements. Approximately two-thirds either already do, or

Figure 2.3 Motivation for enterprise-wide stress testing



Source: IACPM/Oliver Wyman enterprise-wide stress testing survey

plan to, link enterprise-wide stress testing to their planning processes, and to their limit setting and management.

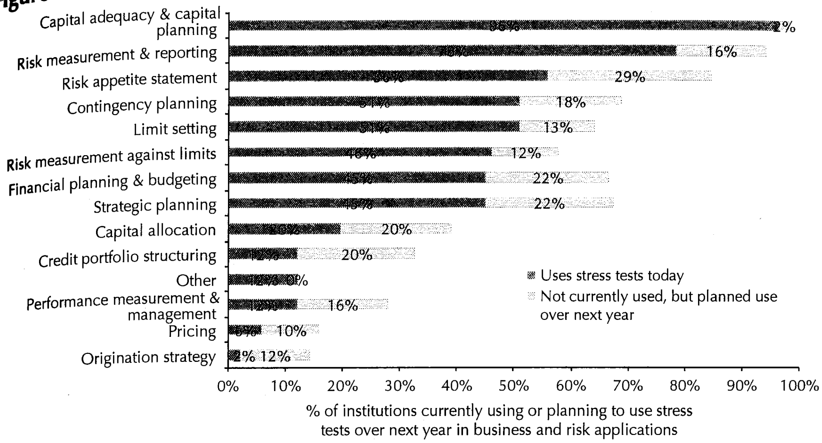
However, many institutions remain focused on improving the underlying approach to enterprise-wide stress testing and the infrastructure that supports it. With continued methodological improvements and growing experience, we expect stress-testing results to be further integrated into business applications such as strategic and financial planning (see Figure 2.4).

Alternative future paths for enterprise-wide stress testing and economic capital

The surveyed institutions overwhelmingly expected to maintain both economic capital and enterprise-wide stress testing as risk management tools. However, maintaining multiple frameworks could lead to challenges in decision-making, as they may appear to generate conflicting results. For example, approximately three-quarters of surveyed institutions intend to continue to develop and maintain both metrics, but only about a fifth reported the reconciling of differences between the two approaches to provide a consistent view of risk.[5]

The industry has not settled on an answer to the question of how to balance stress testing and economic capital. Will the two be applied in largely separate domains, with minimal correspondence or overlap, or will they be used as complementary metrics for the same risks and business purposes? Will banks try to unify their underlying frameworks to the extent possible? Each of these approaches will be discussed below.

Figure 2.4 Use of stress testing by business application



Source: IACPM/Oliver Wyman enterprise-wide stress testing survey

Alternative 1: Economic capital and enterprise-wide stress testing used in separate areas

In this approach, enterprise-wide stress testing becomes a critical tool for capital adequacy, capital management contingency planning, and strategic and financial planning. Economic capital continues to be the primary risk metric for capital allocation, performance measurement and pricing. For other applications, such as limit setting and risk reporting, institutions may make different decisions about whether enterprise-wide stress testing, economic capital or both should be used. In short, this alternative achieves a balance between enterprise-wide stress testing and economic capital by generally avoiding situations where these metrics give different answers to the same question – and hence recommend different courses of action. However, this can obscure inconsistencies that, if seen, would prompt risk analysts to a more thorough interrogation of data or assumptions, and a deeper understanding of the real risk situation.

Alternative 2: Economic capital and enterprise-wide stress testing co-exist as competing measures of risk, with both informing similar applications

Both economic capital and enterprise-wide stress testing are used across many of the core risk management applications. Institutions would accept the various benefits and shortcomings of each metric For cases where the two metrics suggest different courses of action institutions would apply a framework to decide which metric should be given priority for the matter at hand. Such a framework could allow some use of management judgement. However, a well-defined process is needed to avoid bias in selecting the metric to be used.

Alternative 3: Economic capital and enterprise-wide stress testing are integrated into a common framework
In this alternative, institutions find ways of producing enterprise-wide stress-test results and economic capital results using common underlying data, approaches and assumptions. For example, consistent joint approaches for credit risk could involve the combination of a stress-testing platform for evaluating conditional credit losses with an economic scenario simulation generator.[6] This alternative requires significant advancements in modelling capabilities and enterprise-wide stress-testing processes (than achieved to date) in order to measure economic capital.

Economic capital numbers would become more intuitive, because they would be grounded in clearly defined, causal scenarios. Differences in results could then be attributed to accounting-based versus value-based considerations, and to differences in the severity of the stress scenario and the economic capital scenario.

This approach would allow banks to use multiple risk metrics for risk management applications while minimising their potential inconsistencies. Banks would still need to decide when to use which measure of risk, but such decisions could be based on fundamental differences in the metrics and then formalised in policy rather than being evaluated on a case-by-case basis.

ONGOING CHALLENGES IN STRESS TESTING

Despite much progress in enterprise-wide stress testing across the industry, there remain challenges to greater usage in business decision-making. There are methodological and technical issues to meeting users' demands for increasingly granular, accurate and timely information. In addition, there are broader process and organisational challenges that limit the use of enterprise-wide stress-testing results within the institution. These common challenges and "pain points" are listed in Table 2.2.

Table 2.2 Common stress-testing challenges and "pain points"

	Methodology and technical	Process and organisational
Frequently cited	• Data limitations prevent granular customisation • Poor, *ad hoc* infrastructure	• Difficult to coordinate across groups • Excessive manual interventions
Occasionally cited	• Methodologies are not appropriate • Challenges with attributing stress-test results to the necessary level of granularity	• Individual elements of process are too slow • Excessive review periods

Methodological and technical challenges

Challenge: Increased granularity is needed for the tailored use of enterprise-wide stress-testing results

Enterprise-wide stress-testing results must be accurate at the portfolio or sub-portfolio levels to be effective in business applications – such as capital allocation, pricing and performance measurement. So far, however, enterprise-wide stress testing has focused mostly on capital adequacy, which requires accurate results at only the enterprise level. In many institutions, enterprise-wide stress-test results are still relatively crude at position-level or even portfolio-level. Approximately half of the institutions surveyed produce enterprise-wide stress-testing results at the business unit level, and still fewer institutions produce them at the portfolio level.[7]

Achieving enterprise-wide stress-test output with greater granularity requires advances in the following three areas.

☐ *Data:* Institutions identified data limitations as the top impediment to greater use of enterprise-wide stress testing. Over half the surveyed institutions reported that data limitations prevent modelling and customisation at a sufficiently granular level.[8] For example, obtaining good historical data to support loss given default (LGD) modelling is a recognised challenge for many institutions.

☐ *Methodology:* In some institutions, enterprise-wide stress testing is still predominantly top-down, relying on high-level loss regressions, for example. Such top-down approaches may be accurate for the enterprise as a whole but not at more granular portfolio levels, especially when a portfolio's composition has changed over time. Many of the simplest top-down approaches have been replaced by more granular models. However, even some of these granular approaches do not fully take account the characteristics of specific portfolios and changes in their quality over time.[9] For example, commercial loan losses are often forecast using a credit-quality migration matrix. Despite that, many institutions have not modelled the relationship of migration and default to macroeconomic variables based on factors such as industry or company size. To manage this, models can either incorporate more loan-level characteristics into the forecasts directly (that is, as independent variables in the model) or by segmenting the macroeconomic relationships using these characteristics.

- *Segmentation:* Segmentation is a common way of tailoring models to specific sub-portfolios. The segmentation process is often driven by the readily available data or business definitions of segments. Ideally, segmentation would explicitly consider the trade-offs between homogeneity of exposures within a segment, data availability at the granular segment level and materiality of the exposures. In cases where homogeneity and materiality factors indicate the need for a distinct modelling segment but data is not readily available, further avenues such as external data or alternative sources for internal data should be explored.

Although modelling granularity will be an ongoing challenge, we expect significant advances in this area for many institutions. In the US, regulators are pushing institutions to improve the accuracy and timeliness of granular data. They require quarterly submission of loan-level data, as well as pre-provision net revenue (PPNR) related data. Institutions continue to develop data capture mechanisms to support these demands, and will benefit from the improved modelling this data allows. Regulatory guidance[10] has also emphasised the importance of appropriate and systematic segmentation. Demands for greater customisation of model parameters and approaches is also likely to come from business line staff, as enterprise-wide stress-testing results are used in more business applications.

Challenge: Improved data and modelling infrastructure is needed to support enterprise-wide stress testing

Institutions often cite data and modelling infrastructure as a limitation on stress-testing approaches. This infrastructure has an impact on both the range of approaches available to institutions and process efficiency in executing the enterprise-wide stress tests. Difficulties arise because the infrastructure used for stress testing has largely been a collage of tools developed for other processes at financial institutions, such as planning, ALM and *ad hoc* risk modelling. Similarly, the existing data infrastructure has proven insufficient for the needs of enterprise-wide stress testing. The data needed cuts across the organisation and is typically unavailable in centralised systems. As a result, institutions often rely on a patchwork of systems, *ad hoc* tools and manual processes to execute enterprise-wide stress tests. Many of the tools and systems used were not designed to interface with one another, and end-to-end automation that ensures the traceability of inputs through a reliable, consistent platform is not yet available.

These infrastructural weaknesses have impacted both methodologies and processes. Methodologies are stymied by the unavailability of the data needed to execute more customised and sophisticated modelling, especially in the timeframe required of stress testing. Processes are hindered by the many different tools and hand-offs required by the lack of appropriate infrastructure. Institutions that most successfully manage the challenges of stress testing carry out the following two activities.

- *Investing in integrated modelling tools:* The breadth of the enterprise-wide stress testing means that institutions often employ many platforms for the process. Individual risk models, such as those that estimate credit losses, may be combined with financial forecasting platforms. Integrating these various tools greatly increases the efficiency of the process, requiring less effort to complete stress tests within the short timeframes demanded. For example, some ALM tools can also be used to house financial statement data, portfolio data and forecasting models. With the core models embedded in such a central tool, those conducting the stress tests can use their time to ensure the models receive the right inputs rather than on running many

models across the organisation and then aggregating the result
Although this requires significant upfront investment to set u
such platforms can reduce the cycle time from weeks to days.

- *Focusing on consistent data processes:* Some institutions hav designed data infrastructure and processes for enterprise-wid stress testing that are consistent with existing regulator reporting. They rely on shared data infrastructure, thereb reducing the challenges of reconciling the various data used i enterprise-wide stress testing. Alternatively, those that rely o more *ad hoc* portfolio or other data often face process inefficiencies as reconciling to reported balance-sheet data can be complex task.

Process and organisational challenges

Challenge: Clear ownership and governance is critical to an efficient process and to organisational buy-in

Many institutions have struggled to define and agree on an efficien organisational and governance model for enterprise-wide stres testing. About three-quarters of surveyed institutions cited coordination among groups as the biggest "pain points" in the overal enterprise-wide stress-testing process.[11] For example, enterprise-wide stress testing requires the forecasting of new business volume under a stress scenario. Under the baseline scenario in the budgetin processes, business units and financial planning teams often specif their anticipated volumes given market considerations, interna strategy and some constraints, such as the limits defined by the ris unit. To forecast stress scenarios, however, greater involvement is needed from the risk unit as the forecast can have a large impact on anticipated capital ratios. An overly ambitious forecast of volume reductions can distort the view of capital adequacy.

Governance is further complicated by the fact that the key participants – the finance, risk and business units – often approach enterprise-wide stress testing with different perspectives and objectives.

- Business units may have the deepest understanding of the likely behaviour of the business and the market under stress, and they often have the best awareness of the underlying data needed to develop the appropriate models. On the other hand, business units may be reluctant to admit the size of losses they would incur in the stress scenario and thus be inclined to understate risk.

- Finance generally owns the planning process that often forms the backbone of enterprise-wide stress testing, as well as the capital management process that is a key consumer of enterprise-wide stress-testing results. Given the responsibility for capital management, finance has a tendency to focus on achieving appropriate capital returns for shareholders.
- The risk unit is responsible for measuring and managing the risk profile of the institution. However, it often does not house all the capabilities needed to execute the full enterprise-wide stress-testing process. It needs to coordinate with the finance and business units, which can lead to disagreements about the control and ownership of key parameters and processes.

The governance challenge varied significantly across the institutions surveyed. Much of the success observed to date can be attributable to regulatory pressure and resulting senior management attention. The threat of a withheld dividend can be a significant motivator to overcoming organisational and governance challenges. In the US, where the regulatory focus on enterprise-wide stress testing has been very high, institutions were approximately twice as likely as non-US institutions to report that they were highly satisfied with their current organisational model.

This challenge cannot be easily remedied simply by moving accountability or responsibility – the nature of the process is that it inherently cuts across functions. Firms where the organisational and governance model works best tend to have clearly defined accountabilities for each of the major stakeholders, and effective coordination processes for managing the inevitable issues as they arise.

Challenge: Process integration and appropriate resourcing are needed to achieve the level of responsiveness demanded of business applications and key stakeholders

This end-to-end stress-testing process often takes significant time due to the number of participants, range of required models and lack of turnkey solutions. However, regulators have placed increasing demands on institutions to produce results quickly. For example, CCAR institutions in the US have typically seven to eight weeks between the issuance of a scenario and finalisation of capital plans for submission to the regulators. This allows for only a few weeks of stress testing, due to the significant review and discussion needed in the capital management process.

As enterprise-wide stress testing plays an increased role in business applications, the demand for quick execution will also increase. For example, senior management may request *ad hoc* analyses to evaluate the potential impact of a business acquisition. To offer a useful input into such decision-making, enterprise-wide stress-testing analyses would need to be available quickly and reflect current conditions. Processes that are cumbersome and primarily anchored to annual business planning or regulatory reporting calendars will be of limited value for business applications.

Agile stress testing requires the kind of infrastructure development and governance discussed above. It also requires a process that takes account of when data becomes available, when end-results are needed and how long the board of directors and senior management need to review them. Institutions must design the process by "working backwards" from these constraints. There is little room in the process for failed hand-offs, so the content and format required for each link in the process must be clearly specified.

Appropriate resourcing is also critical for the effective and timely execution of enterprise-wide stress testing. Institutions report that having sufficient dedicated resources, as well as external advice and perspectives, are key lessons that have been learned from the past. In general, budgets and resource allocations for stress testing have been increasing. Much of the challenge, however, remains in finding individuals with the appropriate background and skill sets.

CONCLUSIONS

Enterprise-wide stress testing has been rapidly evolving and gaining prominence as an important management tool. It has become widely used as a critical tool for evaluating capital adequacy. Institutions have also begun linking enterprise-wide stress-testing results to risk reporting, planning, limit setting and limit management.

As stress testing exits its infancy stage and becomes a "business as usual" process, institutions face the challenge of how to integrate stress testing more generally into broader risk and capital management applications – such as performance measurement, capital allocation and pricing – and to define the relative role for stress testing, economic capital and (pre-stress) regulatory capital measures. Institutions need to think carefully about the strengths and limitations of each measure, and how they will utilise them together.

Despite the rapid evolution of enterprise-wide stress testing, there remain some key challenges for its further use in decision-making:

- granularity – increased data and modelling granularity is needed for tailored use of enterprise-wide stress-testing results;
- infrastructure – improved data and modelling infrastructure is needed to support enterprise-wide stress testing;
- governance – clear governance is critical to an efficient process and to organisational buy-in; and
- process – process integration and appropriate resourcing are needed to achieve the level of responsiveness demanded by business applications and key stakeholders.

We would like to thank Melinda Sulewski and Terry Tse for their contribution to the ideas in this chapter, and for their editorial and drafting support.

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1 Enterprise-wide stress testing is a process that a financial firm uses to explore the impact of economic scenarios on its financial condition over multiple periods, typically using regulatory capital metrics. The impact is estimated for all businesses and risks, using models that link financial performance to macroeconomic or other factors. In capital adequacy assessment, the "test" is typically whether the institution retains sufficient capital to remain a going concern at the worst point of the forecasted period.

2 The IACPM, with over 85 member institutions located in more than 15 countries, is an industry association dedicated to the advancement of credit portfolio management. Founded in 2001, its programme of meetings, studies, research and collaboration are designed to increase awareness of the value and function of credit portfolio management among financial markets worldwide, and to discuss and resolve issues of common interest to its members.

3 IACPM/Oliver Wyman enterprise-wide stress testing survey.

4 IACPM/Oliver Wyman enterprise-wide stress testing survey.

5 IACPM/Oliver Wyman enterprise-wide stress testing survey.

6 See Daniel Cope and Andy McGee, 2012, "Improving the Measurement of Capital Adequacy: The Future of Economic Capital and Stress Testing", *Risk Journal*, Oliver Wyman, December, available at http://www.oliverwyman.com/media/Improving_the_measurement_of_capital_adequacy.pdf.

7 IACPM/Oliver Wyman enterprise-wide stress testing survey.

8 IACPM/Oliver Wyman enterprise-wide stress testing survey.

9 For a discussion of modelling granularity in the context of PPNR forecasting, see Schuermann, Michael Duane and Peter Reynolds, 2013, "Stress Testing Bank Profitabilit SSRN Working Paper Series, September.

10 See Federal Reserve, 2013, "Capital Planning at Large Bank Holding Compani Supervisory Expectations and Range of Current Practice", August.

11 IACPM/Oliver Wyman enterprise-wide stress testing survey.

3

The Advancement of Stress Testing at Banks

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is chapter will trace the use of stress testing by banks from its cursors to its application following the imposition of regulatory ess tests. It begins with an examination of the origins of stress ting as firms first sought ways to measure risk beyond simple sitivity analyses that were applied to a base set of assumptions derlying capital investment decisions. The application of simu- ed outcomes to probabilistic events led to capital modelling as a y to quantify measures of uncertainty. Economic capital model- g of losses gave banks tools to assess risk-adjusted returns on pital. A number of case examples will be used to illustrate some of early approaches to stress testing that banks used to explore the bustness of their economic capital models and loss estimates.

While Basel II provided the impetus for regulators to charge banks th more formalised approaches for estimating regulatory capital, was only after the emergence from the financial crisis of 2007–08 at stress testing became an important regulatory tool to measure adequacy of banks' capital planning processes. The impact of the ghtened expectations for both regulatory capital and stress- ting approaches has caused banks to downplay their economic pital models. Due to the need for banks to adequately demonstrate ir capital resiliency under severely adverse scenarios prior to their ng permitted to pay dividends or issue stock buybacks, the use by nks of stress-testing outcomes is likely to have a significant impact their portfolio management and capital planning.

EVOLUTION OF RISK MEASUREMENT

To appreciate how stress tests are used at financial institutions, it is helpful to assess their antecedents. In the 1960s, industrial organisations evaluated the attractiveness of capital investments by determining specific inputs that affected cashflows and calculated the associated return on investment. They frequently conducted sensitivity tests that involved varying one input at a time to gauge the impact of an assumed percentage change in input assumptions. This practice was used to determine which inputs were most critical and to lessen the uncertainty of this critical input through additional research and analysis. Estimates of the likelihood of the single input change were sometimes made to estimate better the likelihood of the resulting outcome. However, varying more than one input at a time required connecting these inputs deterministically, and if they were not 100% correlated the likelihood of the outcome could not be easily computed.

In a pioneering article in 1964,[1] David Hertz suggested that risk analysis for capital investments could be better accomplished by constructing probability distributions of all the inputs, along with estimates of their correlations. By convoluting these distributions in a simulation model, it was possible to express the output variable, return on investment, as a probability distribution. Different projects competing for capital could be compared not just according to their expected outcomes, but comparisons could also be made of their variances and relative likelihood of achieving or exceeding targeted rates of return.

Industrial organisations began to pick up on this new analytical technique. For example, in 1967, an income prediction model[2] was developed at the Celanese Chemical Company that involved eliciting subjective probability distributions from key managers of their estimates for product demand, prices, costs of manufacture and raw materials. Pessimistic, most-likely and optimistic estimates in the form of triangular distributions were combined with price–volume relationships, along with material balance and capacity constraints, in a simulation model to produce a probability distribution of income. Other divisions of the company conducted similar exercises and these distributions were further convoluted at the parent level. The overall distribution of income was used to set short-term debt requirements and optimise the size of a revolving credit.

In a post-mortem exercise, the accuracy of the subjective probability distributions was evaluated by comparing the actual outcomes against the range of distributions. In a fair number of cases, the actual result lay outside the probability range and in subsequent exercises additional training was provided to encourage the participants to "spread their tail" estimates and consider more unlikely estimates on both ends of the distributions. The participants also provided detailed documentation to explain the basis for their estimates, and it turned out that this was the most valuable part of the programme. The documentation served as a communication vehicle to their managers and served as hypothetical scenarios.

The development of economic capital models at banks had its origins in the early work at Bankers Trust in the mid-1970s,[3] where a risk-adjustment return on capital (RAROC) was introduced as a way to subject trading and credit extension opportunities to a common risk measure: capital. Rather than measure return on assets employed, return was measured against the riskiness of the assets. Risk was defined as the maximum loss that might be incurred over a specified period of time. The first application was in the trading book, where risk was estimated based on maximum price variations over a specified period. In the late 1970s, the maximum loss measure was replaced with a standard deviation-based measure. JP Morgan refined these estimates using a value-at-risk (VaR) approach and distributed its RiskMetrics model to the public in 1993. Stress tests were mentioned in a number of places, and Philippe Jorion's book on VaR[4] devoted a whole section to stress tests. Harry Markowitz had previously developed modern portfolio theory in 1952, and correlations were introduced in the early 1980s to assess the overall portfolio loss for the trading book using measures such as the maximum potential loss within a one-year period at a 99% confidence level.

EARLY SURVEYS ON THE USE OF STRESS TESTS

The Committee on the Global Financial System (CGFS) of the Bank for International Settlements (BIS) conducted a survey of stress testing by banks in 2000,[5] reporting that most scenarios described shocks to market rates, prices or volatilities. They defined stress testing as a generic term for various techniques used by financial firms to gauge their potential vulnerability to exceptional but plausible events. The most common of these techniques involved the determination of the impact on the entire portfolio or one of its business segments of a move in a particular market risk factor, or a simultaneous move in a number of market risk factors that are linked together either weakly or strongly. These scenarios reflect an event that the firms' risk managers believe may occur in the foreseeable future. The scenarios are either based on actual events that occurred in the past or by constructing a hypothetical but plausible market event. Examples included equity market crashes such as October 1987, rate shocks such as that in 1994, and credit spread widening such as during the autumn of 1998. They concluded that stress testing was primarily driven by data collected in the Treasury departments of banks, and that covered interest rates and foreign currency shocks.

Horizons chosen for economic capital were usually set at one year. This was based on the assumption that the impact of a given stress scenario on the financial system should be followed through time as long as necessary for financial institutions to take remedial action and recapitalise themselves. However, as noted in a BIS study,[6] empirical evidence appears to confirm that, especially during times of generalised macroeconomic turmoil, recapitalisation of distressed banks might take longer than the one-year horizon usually adopted in risk management. Barakova and Carey[7] analysed the behaviour of US commercial banks that suffered large losses and recovered between 1984 and 1999, and concluded that half of undercapitalised banks took longer than one year to rebuild their capital base after incurring severe losses.

In the summer of 2000, central banks from the Group of 10 countries surveyed large international banks about their use of stress tests.[8] The survey responses indicated that stress testing was a standard risk management technique for the participating institutions. All the banks used stress tests to understand their risk profiles and to communicate their risks to senior management. Approximately half the banks used stress tests to conduct contingency planning for times of market stress. One quarter or fewer used stress tests to allocate capital across business lines or to monitor liquidity risk. A majority of the banks used stress tests and asset position to set limits on the size of trades. Risk managers reported a wide variety of responses to a breach of a stress-test limit, ranging from discussions to the mandatory unwinding of positions. They reported that the tests show how risk profiles change over time. All banks reported that stress tests covered securities and derivatives, and two-thirds indicated that stress tests covered their banking book. Only one-quarter of the banks reported that some stress tests integrated market and credit risk in the form of counterparty defaults.

The CGFS conducted a survey of stress testing practices at 64 banks and securities firms in May 2004.[9] They noted that stress testing was used as an adjunct to statistical models and that it was viewed as a complement, rather than as a supplement, to these statistical measures. They also noted the need to develop better stress tests incorporating loan portfolios, as developments in this area lagged those in the market risk by a large margin.

EARLY CASE EXAMPLES OF STRESS TESTS

Not satisfied with historical VaRs measured over a three-month to a one-year period as adequate measures of capital at risk, in the mid-1990s firms such as Chase Manhattan Bank began back testing their then current trading portfolio against historical events. Examples of historical events, or "scenarios" as they were called, included Mexican peso devaluation, the Russian financial crisis and Black Monday in 1987. Chase Manhattan assigned market risk capital using a 50% weight against the VaR measure and a 50% weight against the losses associated with these historical scenarios. In addition, they also developed hypothetical scenarios, such as a "dealer exit". The dealer exit postulates that one major dealer in a particular segment of the market decides or is forced to sell their position over a short period of time, and that creates a liquidity and market valuation crisis, causing other dealers to liquidate their positions in response.

Extensions of economic capital to credit risk were facilitated by the work of KMV, a consultancy organisation in the 1990s that developed option theoretic models to estimate default probabilities of borrowers and their correlations. By the mid-1990s, KMV's Portfolio Manager model was employed at a number of institutions, including Chase Manhattan Bank. This model served as the basis for assigning economic capital to individual exposures based on their contributions to overall portfolio risk. Other credit portfolio models included CreditMetrics and CreditRisk+, both introduced in 1997. Substantial investments were made in the forensic analysis of defaults so as to better establish the basis for estimating default rates associated with credit ratings, exposure at default and loss severities. The capital assigned to individual exposures served as the basis for judging whether transactions met their economic hurdle expressed as return on risk-adjusted capital.

Stress-testing applications for the banking book, especially credit risk, was not as advanced as for the trading book since quantitative analysis of credit risk was a newer discipline. However, in some banks, including Chase Manhattan, stress testing of the wholesale and consumer credit book was employed as early as 1999. The objective was to determine the incremental impact on net income over a two-year period from a stress test based on increased defaults and loss severities while maintaining the loan loss reserve at specific levels. Credit risk scenarios differ from market risk scenarios in that they take longer to unfold, often lag behind economic events and have an impact that is felt over a longer period of time. The stress scenario was built from the 1989–91 recession, and considered not only increased defaults but also migration of credit ratings.

Consumer losses were based on 25% increases in levels of unemployment and a 10% increase in debt-service burden. Resulting bankruptcies and default rates increased by 15% and 20% in the first two years. Wholesale risk profiles shifted negatively based on Moody's transition matrix for 1990. Figure 3.1 shows how the credit rating profile shifted under the recession scenario. Credit exposures that were assumed to mature within one year were extended or replaced at their recession-based migration rates. Figure 3.2 shows how the attendant reserve requirement responded. The bank also used KMV's economic capital model based on default-only losses as opposed to mark-to-market losses. The losses achieved through the Moody's migration scenario corresponded to the 90th percentile of the simulated loss distribution that was constructed as part of the base case. Management felt that the historical migration, which was developed from the worst migration over the previous 10 years, lined up reasonably well with the simulated loss rate distribution.

A more adverse industry scenario was also developed wherein the worst industry historical migration rates were applied to those industries in which the bank had the greatest concentration of speculative ratings. Finally, additional losses were also obtained by

Figure 3.1 Credit portfolio migration under stress

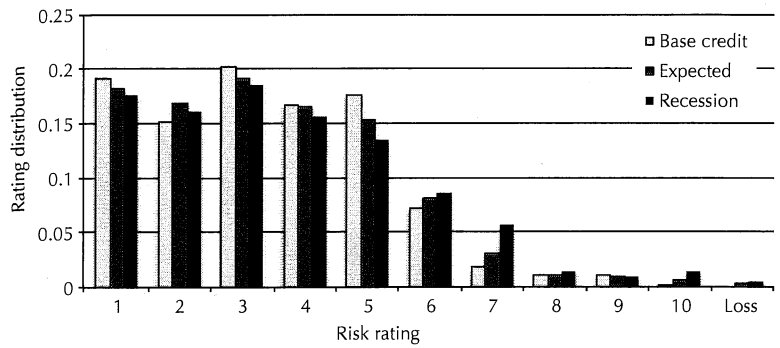
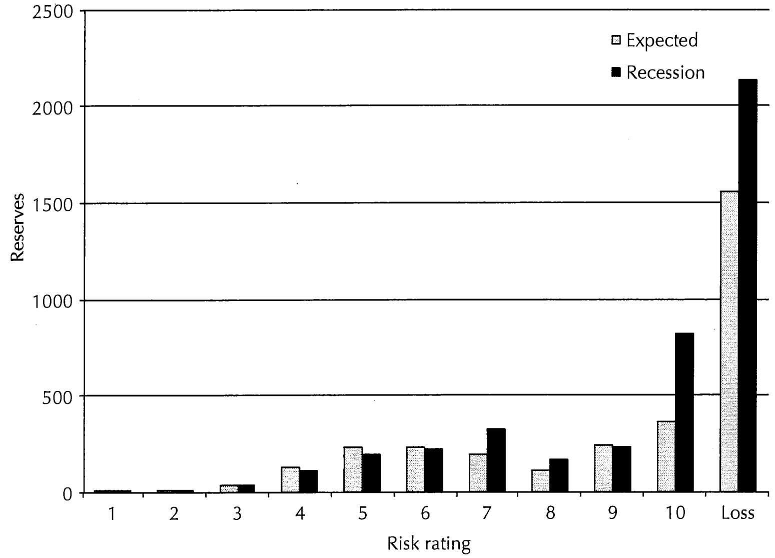


Figure 3.2 Reserve requirement under stress



assuming the five largest sovereign and financial institution exposures defaulted, referred to as "tall tree" defaults. Increased provisions for loan losses replaced the charge-offs and increased reserves associated with the migrated portfolio. It was shown that these losses were not as dramatic as those that had occurred 10 years previously based on a different make-up of the portfolio. Fewer real estate construction loans were in the 1999 portfolio compared to that of 1989. Based on this result, management decided to maintain its low exposure to that sector.

JPMorgan Chase, following the 2001 merger of JPMorgan and the Chase Manhattan Corporation, developed a more integrated stress test. The impetus for this was a potential acquisition of a mutual fund, and the firm was concerned that adverse events might occur that would affect the rating assigned by the credit rating agencies. Discussions with the rating agencies gave the firm some guidance as to the maximum amount of loss that might affect their rating which would affect the desirability of investors to buy shares in the mutual fund. The company developed a hypothetical scenario that had significant increases in interest rates along with value reductions in the equity markets, although the relationship between debt market spreads and equity markets was murky. The interest rate scenario and associated scenarios for credit spreads, foreign exchange and commodity prices scenarios were used to stress the trading book portfolio. Various historical periods were used to determine expected default frequencies (EDFs) for AA and A financial companies, along with Treasury–Eurodollar (TED) spreads. Implied changes in the price of risk were determined. The decline in equity market prices was directly translated into an increase in the EDFs of individual obligors per KMV's option-theoretic model, "Credit Monitor", and a risk-comparable valuation was conducted to theoretically mark the banking book to fair value. Loss severities were also stressed based on the historical increase in loss given default (LGD) during prior downturn periods. Expense increases and other losses from other parts of the business were also identified, and overall losses were calculated and compared to the threshold criteria. Based on these results, management was able to develop confidence in their acquisition strategy.

One area that has begun to benefit from stress testing is the estimation of the allowance for loan loss reserves. For some time, banks have had various approaches to estimating their reserves for loan losses as required by accounting rules. Various banks differed in their interpretation of the horizon under which they were required to estimate losses, some settling on one year, while others extended the horizon to two to three years and others even to the final maturity of the loans. While losses were to be estimated using an "incurred loss" approach similar to that used by insurance companies in their estimates of losses based on "incurred but not reported" (IBNR) events, some banks viewed losses as inherent to the origination of the credit exposure. They conducted forensic analysis of the default rates, loss severities and exposures at default (EAD) to identify the historical losses associated with loans that were in various credit grade categories. In addition to estimating losses arising from defaulted loans as required by the Financial Accounting Standards Board (FASB),[10] they also attached loss estimates to loans that had not yet defaulted. In addition, they also judgementally estimated additional reserves that were not attributable to any specific set of events and which, in some circles, became known as "unallocated". The amount of so-called unallocated reserves varied significantly, from 10–25% of the total reserve to 200–300% of the reserve. For example, in one firm, the management judgement was coloured by the analysis of whether the current portfolio was originated at a time when underwriting standards were tight or weak, and where the firm believed they were in the economic cycle.

Proposals to standardise the accounting treatment of loss reserves between that promulgated in the United States by FASB and by the International Accounting Standards Board (IASB) led to FASB proposing[11] an approach that is not an incurred loss model but an expected loss model, and which requires an evaluation of both historical losses as well as a forecast of losses likely to arise in the future. The results from the stress test and also from their economic model are being utilised as an outside validator of the losses that might arise in the future, and thus place some additional constraints on the range of management judgement additions to the loan loss reserve.

REGULATORY REQUIREMENTS FOR STRESS TESTING

Consolidated stress testing at the firm level was introduced in response to the Basel Capital Accord in 1996, which made approval of the model's approach to a firm's market risk capital requirement conditional on the presence of a firm-wide stress-test programme. However, regulatory requirements for stress testing prior to the financial crisis of 2007–08 were somewhat weak. In the Joint Policy Statement on Interest Rate Risk,[12] the supervisory letter from the Federal Reserve Board (Fed) suggested that bank management should ensure that risk is measured over a probable range of potential interest rate changes, including meaningful stress situations. In developing appropriate rate scenarios, bank management should consider a variety of factors such as the shape and level of the current term structure of interest rates and historical rate movements. They suggested considering a rate movement of plus or minus 200 basis points, as well as changes in the shape of the yield curve in order to capture the material effects of any explicit or embedded option.

Another supervisory letter from the Fed focused on counterparty credit risk.[13] The letter stated that examiners and supervisory staff were instructed to continue and, where appropriate, strengthen their efforts to evaluate whether bank holding companies (BHCs) are moving in a timely fashion to enhance their measurement of counterparty credit risk exposures, including bringing a cross-firm perspective. For these reasons, the Fed's own projections would be expected to differ from the BHCs' projections of their own performance under the same set of hypothetical adverse conditions and from projections made by outside analysts.

As described by Schuermann,[14] banks had significant discretion with regard to the specific design and implementation of stress tests. He further noted that a head of bank supervision at the New York Federal Reserve observed in March, 2007, at an industry conference that no firm had a fully developed programme of integrated stress testing that captured all major financial risks on a firm-wide basis.

The Basel Committee on Banking Supervision reviewed the stress-testing practices of international banks in 2009.[15] They noted that at banks that were highly exposed to the financial crisis and fared comparatively well, senior management as a whole took an active interest in the development and operation of stress testing, with the results of stress tests serving as an input into strategic decision-making that benefitted the bank. Stress-testing practices at most banks, however, did not foster internal debate nor challenge prior assumptions – such as the cost, risk and speed with which new capital could be raised, or that positions could be hedged or sold. Prior to the crisis, stress testing at some banks was performed mainly as an isolated exercise by the risk function, with little interaction with business areas. Risk-specific stress testing was usually conducted within business lines with little firm-wide integration.

Their recommendations for best practices emphasised that stress testing should form an integral part of the overall governance and risk management culture of the bank. The results from stress-testing analyses should impact decision-making at the appropriate management level, including strategic business decisions of the board and senior management. It should cover a range of scenarios, including forward-looking scenarios, and aim to take into account system-wide interactions and feedback effects. Moreover, stress tests should feature a range of severities, including events capable of generating the most damage whether through size of loss or through loss of reputation.

The Supervisory Capital Assessment Program (SCAP) was introduced in early 2009 to assist the supervisory agencies in determining the adequacy of bank capital given the uncertainties associated with the financial crisis of 2007–08. Losses, reserves and capital needs were to be projected by the top 19 BHCs based on baseline and adverse macroeconomic scenarios set forth by the Fed. These top BHCs were asked to determine the impact of these variables on their credit risk, and the top trading banks were asked to also incorporate the impact of these variables on their market risk. This was the first time for US banks that a common set of scenarios were to be set by outsiders. The scenarios specified levels of GDP, unemployment and house prices, and BHCs translated these into increased defaults and loss severities. The trading BHCs were required to translate these variables into changes in rates and spreads and percentage changes in equities, foreign exchange and commodities. All the BHCs were asked to estimate their potential losses on loans, securities and trading positions, as well as pre-provision net revenue (PPNR), and the resources available from the Allowance for Loan and Lease Losses (ALLL) under the two alternative macroeconomic scenarios over a two-year period. The assessment was designed to point out the potential need for a BHC to raise capital or improve the quality of capital to better withstand the losses that could occur under these scenarios and, where needed, create a capital buffer. This framework allowed supervisors to apply a consistent and systematic approach across the group to evaluate the projected loss and resource estimates submitted by the firms.

Some banks developed their own assumptions regarding the levels of these macroeconomic variables in addition to the ones specified by the Fed, and produced their own estimates of capital adequacy. To put further teeth into the exercise, the Fed indicated in a supervisory letter[16] that they would carefully review safety and soundness issues related to payment of dividends, stock redemptions and stock repurchases.

The 2011 Comprehensive Capital Analysis and Review (CCAR) differed from the SCAP. SCAP was a supervisory stress test, meaning that regulators specified the adverse scenario and reviewed the resulting loss and revenue estimates on a standardised basis, drawing on information submitted by each firm. The CCAR process centered on bank-run stress tests in which regulators specified the scenarios but also required each bank to submit their own scenarios in addition to modelling the stress event itself. Moreover, while CCAR had an embedded stress test, the purpose was to assess the BHCs' capital planning processes to ensure that the BHCs had good capital plans in place. Supervisors used independent quantitative techniques both as a check on firm estimates and to assist in their evaluation of the firms' tools and processes. The key evaluation was in terms of the BHCs' capital plans and requests to pay dividends and/or conduct share repurchase programmes.

Regulatory scrutiny of banks' own stress-test responses to scenarios has encouraged banks to validate their models much as the way they employ independent validation groups for their economic and regulatory capital models. While the banks' primary approach consisted of developing various levels of adverse scenarios, the responses to the scenarios were generally based on regressions. The models that captured these responses were termed "champion" models, and the regulators encouraged banks to test the robustness of their assumptions using "challenger" models. The approach that banks follow was to have an independent group examine the model framework and determine whether it fits with their objective for the stress tests. The independent group reviews the underlying model concepts and evaluates how the assumptions, chosen variables, data and interactions meet the model's objective using sound conceptual bases. The challenger model can be developed internally or from external sources. There are vendor models that employ industry data, rather than firm-specific data that can be used as a test. Thus, a challenger model serves both as a validator as well as a benchmark for the bank's own stress-test model. However, care must be taken to ensure that the industry data and experience is applicable to the bank's own profile.

INCREASED RELIANCE ON STRESS TESTS BY BANKS AND REGULATORS

Banks began to seriously integrate the results of the stress tests into their decision-making as they realised the level of importance that the supervisors placed on the capital planning process. As described by the President of the New York Federal Reserve, William Dudley, "Elements of a good planning process include: i) description of risk appetite and capital targets; ii) robust internal controls; iii) incorporation of stress testing and stress-test results into the decision-making process; iv) good governance with respect to the role of senior management and the board of directors; and v) well-articulated capital distribution policies that describe how decisions are made relative to the expectations of future outcomes."[17]

The Dodd–Frank Act (DFA) that was signed into law in July 2010 also mandated annual supervisory stress tests and semi-annual company-run stress tests for all banks with consolidated assets greater than US$50 billion, as well as for certain non-bank financial companies. The requirement was made effective in 2012 for 18 BHCs that participated in the SCAP exercise, with results released in March 2013. BHCs with total consolidated assets between US$10 billion and US$50 billion also were required to undergo annual company-run stress tests. Stress tests for these firms generally begin in 2014.

CCAR 2012 focused on the evaluation and assessment of the capital plans submitted by the 19 BHCs that participated in the 2011 CCAR. The covered BHCs submitted capital projections based on four scenarios: a BHC-defined baseline scenario; a baseline scenario provided by the Fed; at least one BHC-defined stressed scenario; and a stressed scenario provided by the board. The supervisory stress scenario was substantially more extensive than previously defined. It incorporated trajectories for 25 variables, including 13 variables capturing economic activity, asset prices and interest rates in the US economy and financial markets, and three variables (real GDP growth, inflation and the US/foreign currency exchange rate) in each of four countries/country blocks (the euro area, the UK, developing Asia and Japan). For the six BHCs with large trading operations, losses on trading, derivatives and private equity positions were projected assuming an instantaneous re-pricing under a global financial market shock.

Rather than simply reviewing the BHCs' submissions for reasonableness and accuracy, the Fed developed its own analysis of the impact of its supervisory stress test on each of the BHCs based on highly detailed reports submitted by them. The reports captured information on the BHCs' loan and securities portfolios as of September 30, 2011, including borrower characteristics, collateral types, structure of the loans or credit facilities, amounts outstanding and yet to be drawn down (for credit lines), and payment history and current status. The analysis also incorporated the BHC's capital actions – including capital raising, share repurchases and dividend distributions. As part of its review of the capital plans, the Fed generated its own projections of the BHCs' losses, revenues, expenses and capital ratios under severely adverse economic and financial market conditions. As indicated by the Fed, "By examining all 19 BHCs simultaneously, the Federal Reserve was able to enhance its institution-specific analysis with information about peers, applying consistent assumptions and bringing a cross-firm perspective. For these reasons, the Federal Reserve's projections would be expected to differ from the BHCs' projections of their own performance under the same set of hypothetical adverse conditions and with projections made by outside analysts."[18]

In addition to the evaluation criteria described under CCAR 2011, the Fed evaluated a BHC's ability to maintain capital above specified minimum regulatory capital ratios and above a ratio of Tier 1 common capital to risk-weighted assets (RWAs) of 5% under both expected conditions and stressful conditions throughout the planning horizon.

However, the Fed did not disclose the inner workings of its models that translated the stress scenario into impact on capital ratios. A number of BHCs who observed substantial variation between their own assessments of impact and that of the supervisors became concerned that their own assessments had little utility, as what really counted were the supervisory stress-test results. While the Fed refused to provide details of its models out of concern that BHCs would reverse engineer the results, it did form an independent model review committee of subject matter experts from its research divisions who were not involved in the model development.

The differences between the bank's own estimates of loan losses and PPNR was dramatically pointed out in the Fed's analysis of the results associated with the Dodd–Frank stress-tests results reported in 2013. The median of the BHC's own projection of losses was 39% lower compared to that of the Fed's projections (see Figure 3.3). The median absolute difference between the BHC's and the Fed's projection of PPNR was 20% higher for the BHCs (see Figure 3.4).

In their follow-up report of stress tests in 2013, the Fed laid out in great detail their expectations for sound stress testing by banks.[19] They also identified those practices that they deemed weak or strong. In addition to expressing concerns regarding scenario construction, modelling methodology and how banks translated the full range of impact of these scenarios on loss, revenues and expenses, the Fed felt

Figure 3.3 Difference in aggregate loan loss rate projections (Federal Reserve System, FRS, versus BHC models) (%)

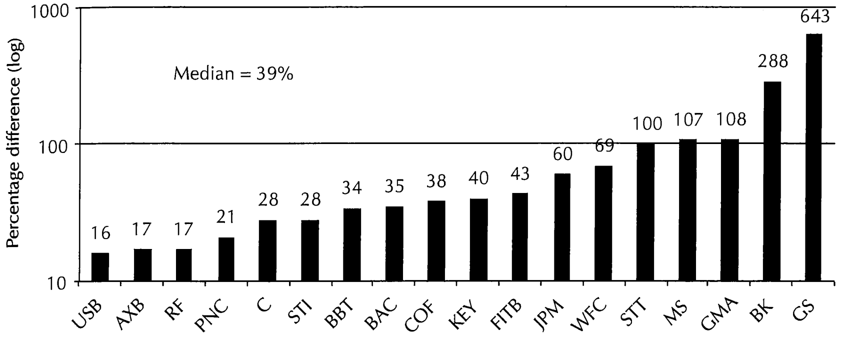
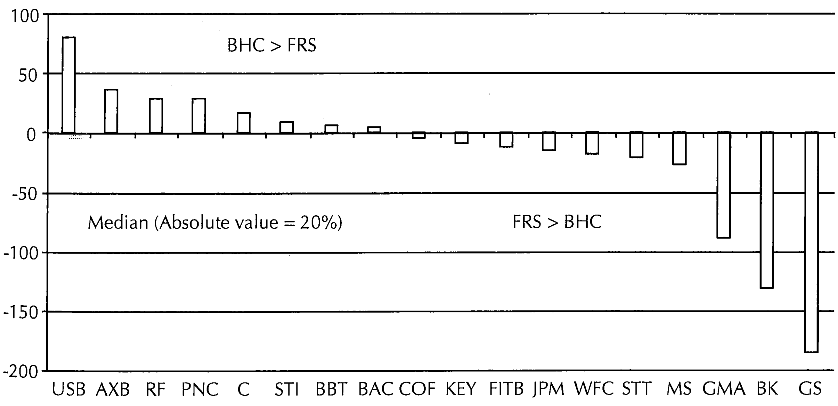


Figure 3.4 Difference in pre-provision net revenue (FRS versus BHC) models (%)



that while credit and market risk were addressed, other risks – including reputational risk, strategic risk and compliance risk – were not. The impact of these risks were not being adequately addressed by some banks, nor had they included them in their capital planning processes. They identified the fact some staff responsible for capital planning operated in silos and developed stand-alone risk inventories not linked to the enterprise-wide risk inventory or to other risk governance functions within their BHCs.

With regard to governance, the Fed believed that BHCs with stronger practices had boards that were informed of and generally understood the risks, exposures, activities and vulnerabilities that affected the BHC's capital adequacy. The directors also understood the major drivers of loss and revenue changes under the scenarios used. The boards of BHCs with stronger practices had sufficient expertise and levels of engagement to understand and critically evaluate information provided by senior management. BHCs with weaker practices provided insufficient information to the board of directors. For example, at some BHCs, capital distribution recommendations did not include all relevant supporting information and appeared to be based on optimistic expectations about how a given scenario may affect the BHC.

In addition, the information did not specifically identify and address key assumptions that supported the capital planning process. Weak practices observed in this area included establishing capital goals based solely on regulatory minimums and the ratios required to be considered well-capitalised without consideration of a BHC's specific capital needs given its risk profile, financial condition, business model and strategies, overall complexity and sensitivity to changing conditions. Some BHCs did not recognise uncertainties and limitations in capturing all potential sources of loss and in projecting loss and revenue estimates, which reduced their ability to establish effective capital goals and targets. Other BHCs were not transparent about how they determined the capital goals and targets in their capital policies.

The Fed also noted that the stress tests revealed the need for better data collection and measurement. Those banks with more granular data are better able to perform bottom-up stress tests. They can segment their historical exposures into meaningful classes of credit exposure and measure their responses to prior downturns and recessions. They can also explore concentrations that might otherwise be hidden. Those banks with weaker data systems that do not enable the forensic analysis of defaults in sufficient detail are forced to conduct more of a top-down analysis of stress-test impacts. For example, banks that are able to attach covenant descriptors to their exposures, both historical and current, are able to determine the degree to which "covenant-lite" loans reacted to prior downturns. Based on their current portfolio composition, they are thus able to project their impact of the stress test on the segment of exposures with common covenant-type characteristics. These banks are better able to translate the stress-test results into portfolio decision-making. Banks with less granular data collection and analysis might respond to stress-test results by saying simply, "We need to reduce our exposure to clients rated Ba2". However, banks with more advanced data analysis are able to provide a more detailed and actionable plan that might be described as, "We need to reduce our covenant-lite exposures in a certain industry and geographic segment." Those banks that have not collected this type of information are unable to determine a more nuanced stress-test impact.

HOW REGULATORY CAPITAL AND STRESS TESTING AFFECTS BANK DECISION-MAKING

As described earlier, the introduction of risk-adjusted return methodology required the estimation of capital based on portfolio models. Significant progress was made in the late 1990s in developing economic capital models and processes. However, as Basel II was introduced in 2004, banks began paying more attention to regulatory capital as an overall constraint. While the key credit risk parameters – probability of default (PD), LGD and EAD – that were inputs to Basel II regulatory capital were to be based largely on the same parameters developed for economic capital purposes, over time supervisors began to question the methodology used to estimate these parameters. Although one tenet of Basel II was to satisfy a use-test, ie, the parameters that were to be estimated for regulatory capital must be used in portfolio and transaction decision-making, the insistence by supervisors to only incorporate empirical evidence in the development of these parameters and to discount the use of credit judgement created a substantial divergence between the parameters that were used for economic versus regulatory capital. In some firms, bank management began to question whether they should have a parallel system that determines regulatory and economic capital or just a single system, namely one just for regulatory capital. However, Basel II required financial institutions to use economic capital as part of the internal capital adequacy assessment process (ICAAP), and banks continued to develop their economic capital models but not with the same investment in systems, methodology and resources as they previously employed. Instead, satisfying the regulatory methodological and reporting requirements consumed the bulk of their available resources.

As Basel II capital requirements transformed into Basel III, additional restrictions were placed on which instruments could qualify for regulatory capital and on the methodology used for assessing RWAs. As a result, banks began to emphasise return on regulatory capital rather than return on economic capital, both for determining line of business profitability as well as some transactional decisions. The 2012 edition of McKinsey's capital management survey of European banks[20] indicated that regulatory capital remained the dominant capital metric, as it has been since the crisis hit in 2007–08, with its use for bank steering and management growing from 70% of banks to 90% between 2010 and 2012. While the use of economic capital has grown even more, with about 70% of banks using an economic capital model, this is primarily to satisfy the requirements of ICAAP with few banks fully exploiting the insights produced from economic capital.

In this author's experience, the reaction of lines of business to increased capital, particularly regulatory capital, created significant concern on the part of the individuals whose line of business was most affected. Despite explanations that many of these methodological requirements were imposed by the regulators and not by the internal members of the quantitative modelling group, they responded with the accusation, "You're killing our business!" To the extent that regulatory risk measures are in fact binding constraints, banks view distortions in how risk is measured as adversely affecting their portfolio decisions, and it is not clear to them as to how they should respond. With years of experience behind them that formed their credit judgements, many bankers are being forced to abandon their key measures of risk and substitute the judgement of regulators without the same experiential background.

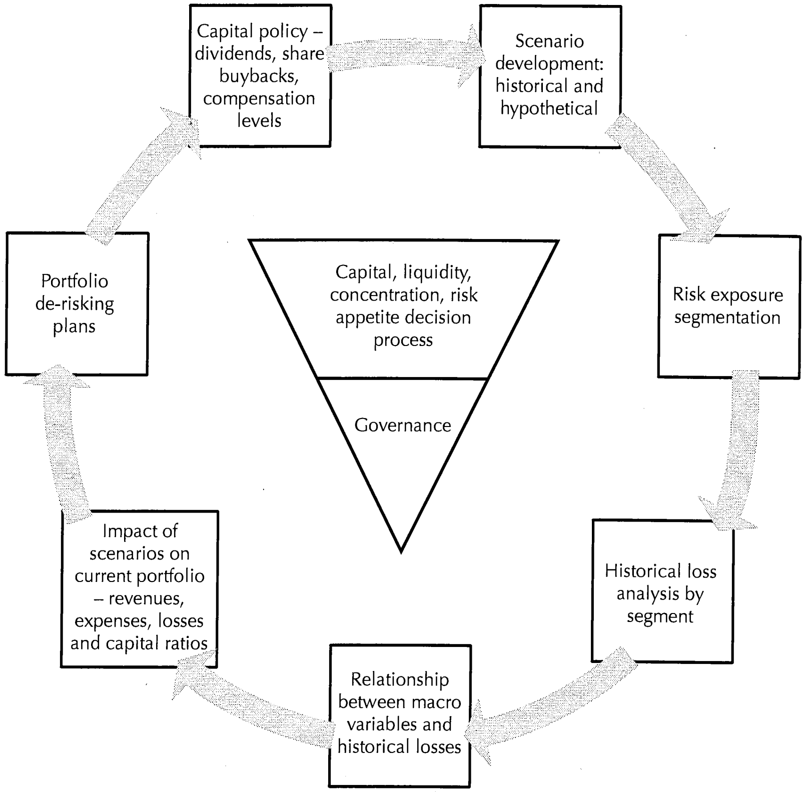
The question then arises as to whether bank management will be making portfolio and transaction decisions and determining profitability using return on stress results rather than continuing to emphasise return on regulatory capital, with a nod toward return on economic capital. It has been observed that various lines of business are becoming increasingly sensitive to the impact of stress tests on their line of business. For example, in one bank the asset and wealth management business was careful to point out where certain assumptions regarding the impact on margin loans associated with stress should be mitigated due to the presence of substantial collateral. While it was not yet clear whether performance management might begin to include return on stressed values, they were keenly aware of a possible new paradigm and beginning to prepare for it.

The process for integrating stress testing into banks' decision-making is illustrated in Figure 3.5. Scenario development considers both historical and hypothetical states of macroeconomic variables. Scenarios that are more closely aligned with the particular bank's risk profile are desirable, as well as those that might be gleaned out of reverse stress tests. It is important to have current risk exposures segmented at an appropriate level of detail, in particular where there are known (or even unknown) concentrations. As indicated earlier, it is essential to have recorded the historical losses and to be able to associate the losses with the same level of granularity as the current segmentation. Often, the current portfolio has more detail than the historical portfolios, as banks have learned over time how to capture important characteristics of their loan portfolio. Unfortunately, it is quite difficult for banks to go back historically and recreate such detail. Historical losses in the form of defaults, loss severities and exposure levels can then be related to prior states of the economy, with regression-based techniques providing some of the statistical support.

The results of these relationships are then applied under the new scenarios to the current portfolio. Analysis of associated income and expenses, losses and capital ratios under the macro-scenario need to be developed. These results are then compared to the desired risk appetite, including capital ratios, and decisions regarding de-risking can be entertained. De-risking options impact the capital policy options governing the firms' dividend, share buy-back and, to the extent considered, compensation policies. The entire process is subjected to governance oversight at every level, beginning with scenario and model validation, to internal controls over data, and finally ending with clear communication and review by senior executives and the various board committees.

As we look back at how stress testing has evolved over time, we can see that banks originally identified stress testing as a helpful tool for assessing risks that were difficult to uncover in sensitivity analysis. Banks developed their own historical and hypothetical scenarios and applied them selectively to risk stripes such as market risk on an ongoing basis, and to credit risk on an *ad hoc* basis, to ferret out areas of potential concern. Only occasionally did banks attempt more of an enterprise-wide stress test that involved marshalling resources from all over the organisation.

Figure 3.5 Stress-test process


Capital policy – dividends, share buybacks, compensation levels
Scenario development: historical and hypothetical
Risk exposure segmentation
Historical loss analysis by segment
Relationship between macro variables and historical losses
Impact of scenarios on current portfolio – revenues, expenses, losses and capital ratios
Portfolio de-risking plans
Capital, liquidity, concentration, risk appetite decision process
Governance

As minimum regulatory capital requirements have been raised substantially, banks have had to incorporate constraints on regulatory capital as part of their portfolio management decisions, rather than rely primarily on return on economic capital. With the increased regulatory emphasis on stress testing and its use in granting banks permission to make capital distributions, banks need to follow the perspectives of regulators regarding the importance of stress testing. It is an approach that, while grounded in the exploration of past relationships of losses with the economic environment, can shed light on vulnerabilities in banks' risk profiles. These need to be imagined based on the possibility that future unforeseen events can create massive holes in their current assumption frameworks. Some banks have started to integrate the results of stress testing into their portfolio management processes, adding the capital constraints associated with the impact of stress tests to their portfolio optimisation processes.

Robert Weber identified two contrasting cultures in the use of stress testing in financial institutions: " stress testing as assurance" and "stress testing as deliberation".[21] The former tends to examine static scenarios, draws from audit cultures, examines tested variables in isolation and is motivated by compliance and verification concerns. In contrast, stress testing as deliberation examines dynamic scenarios, draws from business operations culture, relies on imagination, considers the interactivity of tested variables, remains open to open-ended and uncertain outcomes and is motivated by governance. While at some point when banks were conducting stress tests on their own, they did exercise imagination. For example, they attempted to conduct "reverse stress testing", which starts from a specific result – say, a very high level of defaults or the breaching of VaR limits – and attempts to identify the external, as well as internal, conditions under which these losses could occur.

The regulators have targeted stress testing as a way in which they can encourage banks to use this type of imagination to develop scenarios that are more attuned to a bank's own risk profile. At the same time, by specifying a common set of macro variable assumptions, obtaining detailed data from each bank regarding its own portfolio makeup and using regulatory models, regulators are in a better position to conduct horizontal reviews across banks of their capital planning practices. The issue is whether the stress scenarios developed by the regulators and the impact of these scenarios as determined by the regulators will result in banks using less imagination in their analysis of risk and instead become a compliance exercise.

CONCLUSION

The regulatory scrutiny and criticism of bank stress-testing practices as described by the Fed in their 2013 review[22] is causing banks to approach stress testing very differently than when they first added it to their own risk management processes. Banks viewed the early versions of regulatory stress tests as embodied by SCAP and CCAR 2011 in the light of whether they passed or failed, and little more. This was particularly prevalent in those circles where the regulatory analysis of the impact of the stress tests was treated as somewhat of a "black box" under which the banks had no control over the assumptions used by the regulators in transforming the scenario into portfolio impacts. If they passed and were thus able to continue their share buy-back, dividend payment and executive compensation plans, they did relatively little to learn from the results of the stress tests. If they did not pass, they began to try to understand what were the largest contributors to the stress-test results and began to question their own portfolio decisions. Thus, to some extent, stress testing that was originally viewed by banks as helpful to understand their risks and make contingent plans for the potential realisation of these scenarios, lost much of its value as the banks viewed passing the stress tests as threshold requirements.

While the banks do not yet have a great deal of insight as to how regulators are translating the stress scenarios into portfolio impacts and resulting capital adequacy assessments, the stepped-up expectations by the regulators of the capital planning processes has been causing banks to seek ways to better incorporate the results of the stress tests into their decision-making. The degree to which banks will become more reliant on stress-test capital requirements as opposed to those based on economic capital is as yet uncertain.

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4

Designing Macroeconomic Scenarios for Stress Testing

Mark M. Zandi

Moody's Analytics

Since the financial crisis broke, central banks around the world have taken unprecedented steps to revive the global economy. Ultra-low interest rates and ballooning central bank balance sheets have been the subject of much debate. Receiving much less attention, but arguably just as important, are the stress tests that financial regulators now require large institutions to take.

Stress testing emerged in the US and UK during the height of the financial crisis in early 2009. The financial system had suffered a near-death experience: major institutions had failed, stock markets had fallen and credit markets had frozen. While governments managed to prevent calamity through unprecedented fiscal and monetary policy actions, no one knew whether this would be a temporary fix or a lasting cure. The US Treasury and Federal Reserve designed stress tests for the nation's major financial institutions, to determine the amount of capital needed to restore their health to health. Banks were required to quantify what could happen to their mortgages, credit cards and other portfolios if the economy suffered a downturn as severe as the 1930s Great Depression.

Many viewed the stress tests sceptically. Some called them simply window dressing: a way to convince the public that banks were solid even if they were not. President Roosevelt used a similar sleight-of-hand to restore confidence in the banks when he took office in 1933. Roosevelt declared a "bank holiday", after which only "good" banks would reopen. There would thus be no reason to pull money out of good banks. The ruse worked; the bank runs ended. It later turned out that the administration was not sure the reopened banks were solid, and indeed knew that some were not. The president of the San Francisco Fed had insisted that Bank of America, the largest bank on the west coast, was insolvent. However, Roosevelt feared widespread panic if Bank of America did not reopen, so it did.

Bankers also protested that the stress tests were overly complicated, and would force them to go hat-in-hand to investors for more capital. Worse, if banks could not raise capital from private sources they would have to accept it on punitive terms from the government. Regulators overruled the critics, imposing tests that were far from mere window-dressing. Banks were required to consider what would happen if unemployment rose into the double digits and house prices fell by more than 50%. What they found was stunning: over two years, the banks would suffer cumulative losses comparable with those seen in 1933 and 1934, the worst two years of the Depression.[1] Financial institutions banks would need tens of billions of dollars in new capital to survive such a scenario.

The regulators were vindicated; the stress tests worked. The banks recapitalised, reassuring markets and themselves that the system was sound. Just a few months after the US financial system had been at death's door, it was up and running again. Stress testing has since become a standard part of global banking regulation, adopted by the International Monetary Fund for all its member countries. The largest financial institutions in the world test each year. Bankers no longer complain, viewing the process as critical for robust risk and capital management.

Bank stress testing saved the global financial system and helped forestall another economic depression, and it remains critical to a well-functioning financial system. Well-designed macroeconomic scenarios are extremely important for ensuring that stress testing continues to play a positive role.

This chapter will consider the appropriate design of macroeconomic scenarios for stress tests, and some tools and approaches that are available for this purpose. More specifically, the chapter will begin with a discussion of some of the overarching criteria that should underpin scenario design. Modelling approaches used to implement scenarios are discussed, and a methodology for constructing baseline, alternative and idiosyncratic scenarios is presented. The chapter also provides a modelling approach and methodology for determining the probabilities of these scenarios. Much of what is presented here is based on work carried out at Moody's Analytics, and thus is only one approach to designing and effectively implementing macroeconomic scenarios for stress testing.

STRESS TESTING SINCE THE CRISIS

Stress testing has grown more sophisticated since early 2009. At that time, only the very largest US financial institutions were required to determine the loan losses they would suffer if US GDP and house prices fell sharply and unemployment surged. However, by 2015 most institutions across the globe will be testing all aspects of their operations under a wide range of macroeconomic scenarios. How these scenarios are constructed is key to ensuring that the stress tests promote a sound global financial system, which in turn can determine how much credit flows to the economy, what that credit costs and what activities it funds.

Scenarios should be designed to account for the risks most threatening to the financial system. In 2009 and 2010, the largest threat stemmed from losses on US mortgage loans. In 2010 and 2012, it was the potential for a break-up of the eurozone. Latterly, it has become the eventual exit of central banks from their zero-interest rate and aggressive bond-buying policies.

Each financial institution should also consider scenarios that stress its own idiosyncratic exposures and potential vulnerabilities. Some institutions have concentrated regional footprints, do more business in certain parts of the world, are focused on certain types of lending and investing, or rely on particular funding sources. The severity of the scenarios financial institutions stress should reflect the macroeconomic, lending and funding conditions at the time a test is conducted. When leverage is high and rising, and underwriting is easy, the odds of a deeper downturn rise. If stress tests had been the norm in the early 2000s, they might have helped regulators curb the runaway mortgage lending that inflated the housing bubble in the US and some European nations.

Conversely, overly stringent stress tests when leverage is low and falling, and underwriting is tight, could require financial institutions to hold too much capital and restrict credit, stunting economic growth. In a tough economic climate, this would hamper the global recovery. In addition, it could curtail investment in riskier but ultimately productive innovations, such as information technology and clean power, which have improved living standards. Poorly designed stress-testing scenarios could also stifle financial innovation. By definition, new financial products have no track record; thus, the historical data needed for rigorous analysis are lacking. Macroeconomic scenarios should be designed so that financial institutions and regulators do not penalise new financial products that cannot easily be assessed quantitatively.

There is also a risk that stress testing will foster financial protectionism. Most major banks maintain global operations, and the stress tests rightly consider global economic conditions. However, regulators could force banks to hold more capital against overseas loans, prompting them to do less foreign lending, if they are stressing to a macroeconomic scenario in which the global economy is hit by an overly severe downturn. Like any test, these encourage test-takers to focus simply on passing. This could mean that banks' models and risk management methods will grow to look alike, and that lending practices will become increasingly uniform. The problem will be worse if macroeconomic scenarios favour some types of lending over others. Banks could herd in the desired direction, threatening financial stability.

Financial institutions that undergo stress tests may avoid some risks, but those risks may simply move to another, less visible, part of the financial system where there are no stress tests and regulators have little influence. Macroeconomic scenarios must therefore also account for risks in the shadow banking system where there is no formal stress testing.

MODELLING APPROACHES

While many approaches can be used to formulate macroeconomic scenarios for stress tests, the most common involves the use of structural macroeconometric models.[2] Although not perfect, structural models can capture the relationships among a wide range of variables across many global economies, a necessary requirement for robust stress testing.[3]

In the US, structural models are used regularly by the Federal Reserve Board and other regulators, as well as by the Congressional Budget Office and the Council of Economic Advisers. The model for the US is particularly large, with 1,700 equations. Structural models can adapt with relative ease to a shifting economic and policy environment. The Moody's Analytics US model, for example, was enhanced in the wake of the financial crisis to capture the impact of many new financial policies, most of them unprecedented and unconventional, including the capital raised by financial institutions to meet the requirements of the early 2009 stress tests.

This is captured via the equation for the spread between three-month Libor and three-month Treasury bills (the TED spread), which is modelled using two-stage least-squares techniques as a function of the delinquency rate on commercial bank loans and leases, the market value of equity lost in failing financial institutions during the financial crisis, the S&P 500 VIX index and the amount of capital raised by the banking system via the Capital Purchase Program (CPP) in the Troubled Asset Relief Program (TARP) and the bank stress tests.

The rationales are straightforward: as the delinquency rate increases, banks demand higher interest to lend to other banks. The equity lost in failing institutions captures the growing panic that investors felt as the crisis intensified. The VIX is included to capture the impact of broad financial market volatility on credit spreads, and initial unemployment insurance claims are used as an instrument for the VIX to account for any issue with endogeneity. The capital raised by banks, either from the federal government or in the equity market, captures the benefit of the stress tests in restoring stability to short-term funding markets. Based on this equation, the capital required by the stress tests reduced the TED spread by some 200 basis points.

Another model innovation that should be identified given some of the criticism of structural models is that monetary policy is endogenously determined in the model, and does allow for quantitative easing. The federal funds rate equation is based on a so-called Federal Reserve reaction function, in which the real funds rate target is a function of the economy's estimated real growth potential, the difference between the actual and target inflation rate, and the difference between the actual unemployment rate and the natural rate. This specification is augmented to include the difference between the presumed inflation target and inflation expectations, as measured by five-year, five-year-forward Treasury yields.

Because of the Federal Reserve's extensive use of quantitative easing to respond to the financial crisis, the value of assets on the

Federal Reserve's balance sheet was added to the model. Fed assets are specified as a function of the federal funds rate target. When the funds rate implied by the equation falls below zero, the Fed's balance sheet expands. Also, the more negative the implied funds rate, the greater the assumed balance-sheet expansion.

Specifically, for every 100 basis points that the desired (but unachievable) funds rate becomes negative, the Fed is presumed to expand its balance sheet by US$1.2 trillion. In 2013, at the time of writing, the implied funds rate is negative 2.5%, which is consistent with the Fed holding close to US$4 trillion in assets. Fed assets and the funds rate are, in turn, key determinants of 10-year Treasury yields in the model.

Another common criticism of structural models is that they do not account for the important role expectations play in determining the economic impact of fiscal policy. In fact, the outlook for the federal debt-to-GDP ratio is a key variable in the model, affecting monetary policy and long-term interest rates via inflation expectations and real yields, and by extension current spending, saving and investment decisions. It is perhaps telling that inflation expectations and real long-term Treasury yields remain low despite large budget deficits, ostensibly reflecting in part expectations that lawmakers will eventually address the nation's fiscal problems.

BASELINE SCENARIO

The design of macroeconomic scenarios for stress testing begins with a baseline, most-likely scenario. This baseline is designed to fall in the middle of a distribution of possible economic outcomes. Since the chances of the economy precisely realising any specific time path, no matter how reasonable, are small, the baseline is viewed as representing an outcome in which there is a 50% probability that economic conditions will be worse and a corresponding 50% probability that they will be better over the forecast horizon.

The Federal Reserve, in designing the baseline scenario for the annual Comprehensive Capital Analysis and Review (CCAR) stress-testing process, relies on a consensus of macroeconomic forecasters who are surveyed each month. Consensus economic surveys generally provide forecasts for a handful of economic variables with a horizon of just a few years, and this varies considerably across countries. The Federal Reserve uses its structural model to produce forecasts for a broader range of economic variables and a longer horizon than is available from the consensus, but it is generally consistent with what consensus information is available.

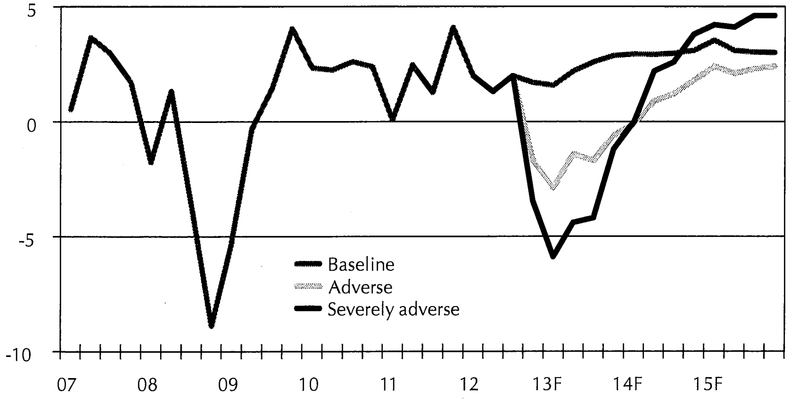
Moody's Analytics produces a baseline scenario for the US, individual states, metro areas and counties, and for 60 other countries each month. The assumptions underlying the forecasts are consistent across the globe. While the baseline is not necessarily consistent with consensus forecasts, most times the differences are small.

FEDERAL RESERVE'S CCAR SCENARIOS

Most alternative macroeconomic scenarios used for stress testing are more pessimistic than the baseline. The Federal Reserve, in its CCAR, produces two alternatives to the baseline: an adverse and a severely adverse scenario. The severely adverse scenario envisions a sharp economic downturn in which the economy descends quickly into a recession on par with that experienced in 2007–09 (see Figure 4.1). Forecasts are provided for a dozen or so economic variables for the US, the UK, Japan and emerging Asia.

The Fed does not provide an explicit narrative for its recession scenario, complicating the task of expanding it to other economic variables and other countries. However, Moody's Analytics constructs a plausible narrative based on the forecasts provided by the Fed and an understanding of the key threats to the global

Figure 4.1 Federal Reserve's 2013 CCAR macroeconomic scenarios (US real GDP % change, annual rate)



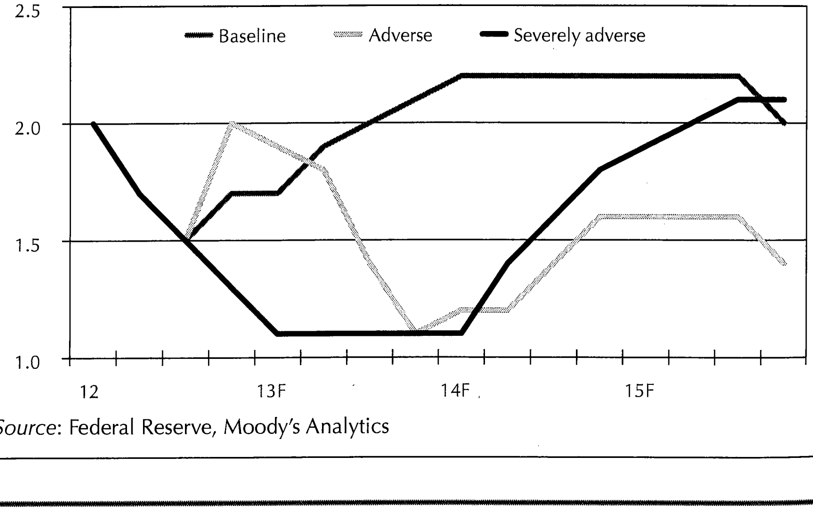
economy. In the 2013 CCAR severely adverse scenario, for example, the key threats appeared to be a break-up of the eurozone combined with a sharp slowdown in China recession and severe fiscal drag in the US. This narrative is used to expand the Fed's forecasts to a broader set of variables and countries.

The Fed's adverse scenario stresses financial institutions under difficult conditions that may not be entirely realistic. That is, the odds of the specified adverse scenario occurring may be low, but anything like it could do significant damage to the financial system. In the 2013 CCAR, the adverse scenario included an immediate increase in inflation and interest rates and a flattening in the Treasury yield curve (see Figure 4.2). It was not clear what would produce this outcome, but such a scenario would be very hard on the profitability and capital of financial institutions, especially after a long period of exceptionally low interest rates. If banks could weather this unlikely storm, they could arguably weather almost anything. Running the Fed's adverse scenario through the structural models was more challenging given the lack of a narrative.

ALTERNATIVE SCENARIOS

Moody's Analytics produces a number of alternative scenarios each month along with the baseline. The same hypothetical events drive

Figure 4.2 Fed's 2013 adverse scenario includes a flatter yield curve (10-year Treasury yield less three-month Treasury bill, %)

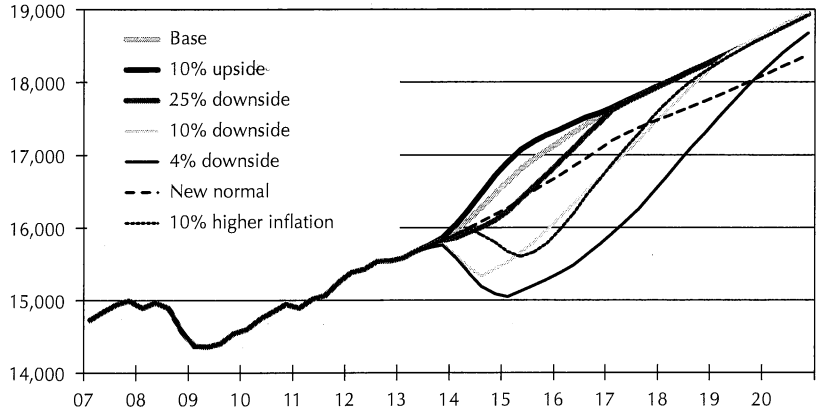


Source: Federal Reserve, Moody's Analytics four of the alternative scenarios, but they occur with varying intensity. The three downside scenarios have a one-in-four, one-in-10 and one-in-25 probability, respectively, while the one upside scenario has a one-in-four chance of occurring (see Figure 4.3). In other words, the one-in-four probability downside scenario is constructed so that there is a 75% probability that the economy would perform better over the forecast horizon and a 25% probability that it will perform worse.

How well the economy performs in each scenario depends on the economy's underlying condition at the time the scenario is constructed. For example, a one-in-25 downside scenario would mean a higher peak unemployment rate when the economy was in the middle of the Great Recession, than it would when the economy is growing. This differs from the Fed's CCAR scenarios: the peak unemployment in the 2013 CCAR severe adverse scenario is similar to the peak unemployment rate in the 2009 scenario. The Fed is thus effectively requiring financial institutions to capitalise to a much less likely economic outlook in 2013 than it did in 2009.

A consistent economic narrative underpins the alternative scenarios. Explicit hypothetical events push the economy away from the baseline outlook. Since many possible events could produce the same downside outcome for the economy, the events included in the

Figure 4.3 Real US GDP in Moody's Analytics scenarios (2009, US$ billions)



Source: BEA, Moody's Analytics

scenarios are considered most likely at the time the scenario is constructed. For example, in 2013 the main events driving the downside scenarios include a US political crisis around the federal government's budget and Treasury debt limit, a revival of the eurozone debt crisis, higher gasoline prices and a renewed decline in house prices.

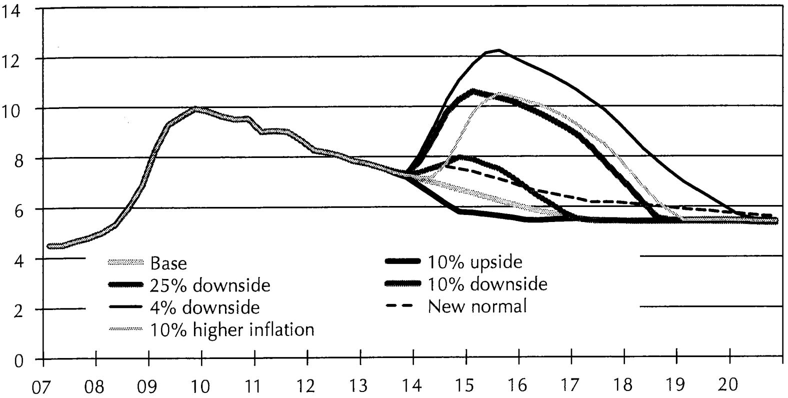
Different scenarios are driven by the same events, but with varying degrees of severity. The one-in-10 downside scenario, for example, is driven by the same events as the one-in-four downside scenario but with more significant changes from the baseline. Similarly, the contours of the one-in-25 downside scenario are similar to those of the one-in-10 downside scenario, but even more severe.

The events driving the scenarios are captured in the structural model through many variables that are adjusted to produce the alternative scenarios. Some of the most commonly used are fiscal and monetary policy, global real GDP, the value of the US dollar, oil and natural gas prices, stock prices, housing values, consumer confidence, banks' lending standards and inflation expectations. The variables are used parsimoniously, allowing the model to generate as much of the results as possible.

Most alternative scenarios assume that the economy's long-term potential growth rate and full employment unemployment rate are unchanged. That is, the economic downturn does not damage the economy's ability to grow as fast as it did before the recession or impair the productive capacity of the economy. Real GDP and unemployment in the alternative scenarios ultimately return to their paths in the baseline (see Figure 4.4). This also appears to be an underlying assumption in the Fed's CCAR alternative scenarios.

It is important to note that if an economy's potential growth rate is not affected by a recession, then there must be a period of above-potential growth in the recovery for the economy to return to its pre-recession, full-employment level. The economy will grow strongly at some point in the recovery as under-utilised labour and capital are put back to use. This may seem counterintuitive in a downside alternative scenario, but it is a regularity of past business cycles and must occur if economic activity is to ultimately return to its pre-recession baseline level. Indeed, the deeper the recession, the stronger the subsequent economic growth, although the timing of

Figure 4.4 Unemployment eventually returns to baseline (US unemployment rate, %)

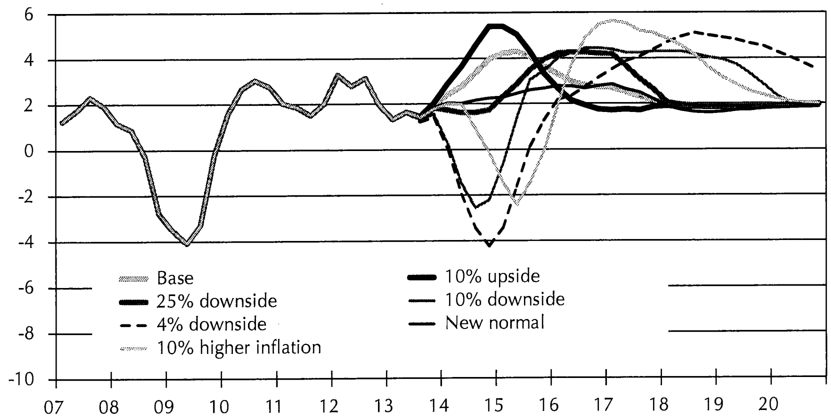


Source: BLS, Moody's Analytics

when that outsized growth occurs is uncertain (see Figure 4.5). This is clearly evident in the lacklustre global economic recovery from the Great Recession.

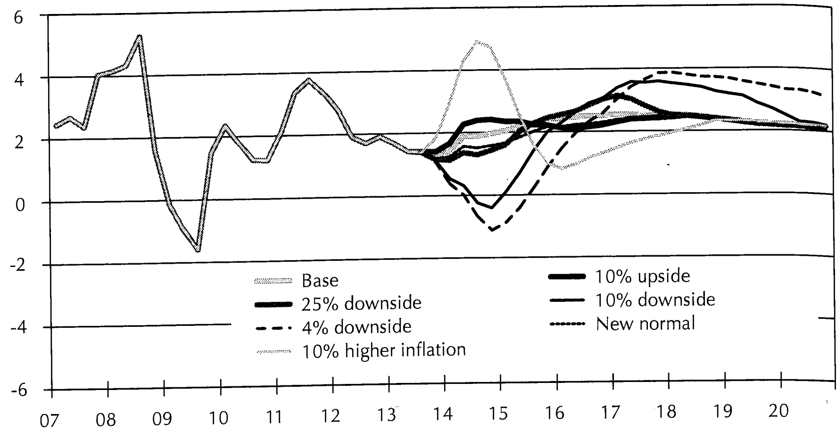
There is a reasonable debate around this assumption, as some argue that growth rates have weakened to a "new normal" due to the

Figure 4.5 Deeper recessions … stronger recoveries (eventually) (US real GDP growth, % change year ago)



Source: BEA, Moody's Analytics

Figure 4.6 Fed loses control of inflation in high-inflation scenario (US consumer price inflation, % change year ago)



Source: BLS, Moody's Analytics

severity of the Great Recession. Economies suffering similar financial crises throughout history have taken many years to regain their footing. Indeed, the economy has been growing at a slow pace since the recovery began, and there is compelling evidence that the economy's full-employment unemployment rate is higher, with long-term unemployment at unusually high levels. As such, Moody's Analytics produces an alternative scenario characterised by economic growth that remains below its pre-recession potential rate indefinitely. This scenario has one-in-25 probability.

Also particular to the economic conditions prevalent in 2013 is the concern that inflation will accelerate sharply. Those who worry about this point to the enormous increase in the Federal Reserve's balance sheet since the crisis, and the potential for energy and other commodity prices to rise due to strong demand from emerging economies and political tensions in commodity producing countries. Much higher near-term inflation is thus the basis for another alternative scenario, which has a one-in-10 probability of occurring (see Figure 4.6).

DETERMINING SCENARIO PROBABILITIES

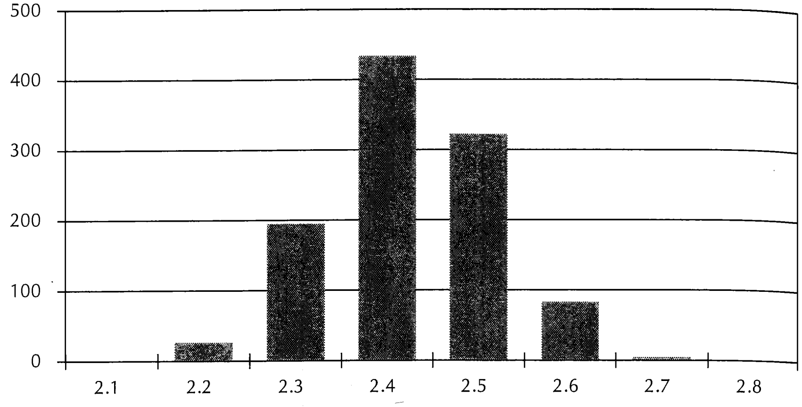
The probabilities associated with each of the alternative scenarios are derived based on the use of vector autoregression (VAR) models of the US and other global economies. While structural econometric models are used to construct the alternative scenarios, they are too large and complex to be used for determining the probabilities of those scenarios. VAR models are well-suited for this purpose.

The use of VAR models in economic forecasting first began to grow in the early 1980s.[4] A VAR model includes a relatively small set of equations specified so that the only explanatory variables for each equation are the lagged values of the dependent variable itself and the lagged values of all the other variables in the model. In other words, the explanatory variables are the same for each dependent variable. VAR models are completely agnostic about structural relationships in the economy. For example, economic theory says that there is a positive relationship between consumer spending and disposable income, but the relationship in a VAR model could be negative.

The US VAR model used for the purpose of determining the probability of alternative scenarios includes all the major components of real GDP, allowing real GDP to be computed as an identity. Other variables included in the model are the unemployment rate, consumer price index, the three-month Treasury bill rate and the 10-year Treasury bond rate. Key exogenous variables in the US VAR model include the output gap (measured as the difference between actual and potential real GDP) and the full employment unemployment rate of unemployment (the unemployment rate consistent with stable inflation). Other exogenous variables include oil prices, global real GDP growth and the trade-weighted value of the US dollar.

VAR models are not very useful in constructing alternative scenarios for stress testing since they are generally too small, and it is difficult to explain their results. However, they are useful in determining the range of possible economic outcomes via Monte Carlo simulations. This involves running thousands of simulations accounting for the uncertainties involved in the VAR's relationships. The VAR models are thus constructed to predict history accurately and, just as importantly, to produce realistic Monte Carlo simulations. Each simulation determines a new path for the economic outlook. Taken together, the simulations provide a distribution for possible outcomes for the economy. In a Monte Carlo simulation of the US VAR model, the mean of the distribution of average annual

Figure 4.7 Real GDP growth outlook is centred around 2.4% (no. of simulations; annual average real US GDP growth, %)



Source: Moody's Analytics

real GDP growth rates was about 2.4% per year, which is consistent with the historical performance of the US economy (see Figure 4.7).

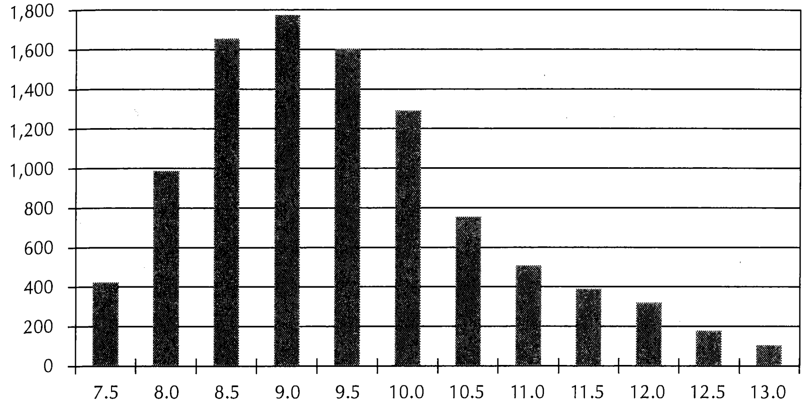
The distribution of possible economic outcomes provides the information needed to assign probabilities to the alternative scenarios. More specifically, the distribution of the unemployment rate outlook, arguably the best overall barometer of an economy's performance and an important variable in most stress tests, is used to calculate the probabilities (see Figure 4.8). For example, if only 4% of the simulations have a peak unemployment rate that is greater than 12%, then a 12% peak unemployment rate would define a one-in-25 alternative scenario.

The distribution of possible economic outcomes depends on the economy's starting point. If the economy currently has a low unemployment rate, then the peak unemployment rate in the one-in-10 scenario, for example, will also be lower.

SUB-NATIONAL, COUNTRY AND HOUSE PRICE SCENARIOS

Since most US financial institutions have footprints that do not include the entire nation, Moody's Analytics also produces baseline and alternative scenarios for US states, metropolitan areas and counties. As with the national scenarios, those for sub-national economies are based on structural models. The models account for the different

Figure 4.8 Distribution of peak unemployment rate (no. of simulations; peak US unemployment rate, %)



Source: Moody's Analytics

industrial structures, demographic make-up, and business and living costs across the country. Events such as a financial crisis, government shutdown or surging energy prices will thus produce different regional economic consequences.

Different domestic and foreign migration patterns are also accounted for in the models, since they can have a large impact on the performance of sub-national economies. Inflows of migrants looking for jobs in energy-producing regions such as Texas and North Dakota have fostered even faster growth in these areas. Conversely, migration out of industrial midwest states such as Michigan and Ohio has exacerbated the downturn in these areas.

The Federal Reserve's CCAR scenarios are silent with regard to regional economic performance, although Moody's Analytics do produce regional scenarios consistent with the Fed's national CCAR scenarios. This requires the construction of narratives around the Fed's scenarios. If the recession in the Fed's severely adverse scenario is due to a eurozone crack-up, for example, this will have a larger impact on the northeastern US, which trades extensively with Europe, than on California, which trades more with Asia. However, if the recession is due to a federal government shutdown, the Washington DC region and defence-dependent regional economies will be hit hard, but other regions much less so.

As an aside, a similar problem exists with the Fed's CCAR scenarios for overseas economies. The Fed provides baseline and alternative scenarios for the eurozone, for example, but not the eurozone's member nations. Yet a eurozone break-up would clearly affect these nations in very different ways, leaving Germany, for instance, in a very different place than, Greece, say. How different will depend on the narrative behind the hypothetical event. A plausible narrative consistent with the Fed's forecasts is constructed and used to build scenarios for each eurozone country.

Given the increasingly instrumental role of housing in the financial system and the economy, detailed house price models for stress testing have also been developed. Metropolitan area repeat-sales house price indexes are modelled using an error-correction specification that accounts for both the long-term trend in house prices, which depends on household incomes and rents, and factors that drive prices up and down around that trend, such as changing mortgage rates, credit availability and unemployment. The model specification allows for house prices to become significantly overvalued and also to correct quickly. Since housing markets are inherently regional, constructing reliable house price scenarios depends on scenarios for regional economies.

IDIOSYNCRATIC SCENARIOS

Increasingly, regulators are also requiring financial institutions to conduct idiosyncratic stress tests. Each institution has a unique set of exposures and vulnerabilities, and regulators want them to develop their own baseline, adverse and severely adverse scenarios to best reflect those risks. Idiosyncratic stress testing began in earnest in 2013, and will be an important part of the Fed's stress-testing process in the future.[5]

An idiosyncratic stress test conducted by an institution operating in the US midwest, for example, may concentrate on lending to vehicle manufacturers, dealers and suppliers. A southeastern institution, on the other hand, may focus on commercial real estate lending in Florida. Another institution could rely more heavily on non-deposit funding or be a big player in providing custodial services to other financial institutions. Some institutions have large securities holdings whose value is especially sensitive to rising interest rates.

In an idiosyncratic stress test, each institution must identify its own sources of vulnerability, assume events can expose these vulnerabilities and determine what would then happen to the institution's profitability, capital and liquidity. In the extreme, the institution could ask itself under what conditions it would exhaust its capital or liquidity, and thus fail. This is a reverse stress test.

Moody's Analytics models can be used to construct idiosyncratic stress tests. This involves identifying institutions' exposures, developing scenarios that would stress these exposures and quantifying these scenarios with structural models of the economy. While the Federal Reserve is opaque with regard to the severity and length of the stresses institutions should consider, a reasonable approach is to assume a downturn that is at least on par with the Fed's severely adverse scenario, but focused on the institution's own vulnerabilities.

The Fed is also quiet about these scenarios regarding the timing of the downturn. In its CCAR scenarios, the downturn begins immediately; that is, in the quarter in which institutions are testing. This is generally not very realistic, but simplifies the testing process since institutions can avoid making significant decisions about their future lending and funding practices. However, in an idiosyncratic test, institutions may want to assume that the downturn begins later, and after the institution takes on even more risk. This would create a higher bar, and provide confidence to regulators the institution is on solid financial ground.

CONCLUSIONS

Stress testing was instrumental in pulling the global financial system through the financial crisis. The tests forced financial institutions to recognise their problems and address them, not only to the regulators' satisfaction but to their own. Once bankers saw the tests were truly substantive, and realised that it meant they were capitalised well enough to withstand the flagging economy, they also knew their counterparties were equally solid. The financial turmoil immediately subsided, allowing an economic recovery to begin.

Stress testing has become much more comprehensive and complex. Financial institutions are required to consider what will happen to their balance sheets, income statements and their entire enterprise under a range of scenarios, some constructed by regulators and others constructed by themselves. This creates a wide range of questions regarding how to effectively and efficiently implement these tests.

One of the key questions is how to construct macroeconomic scenarios that realistically test the health of financial institutions and the financial system. This is difficult to answer given the limits of macroeconomic information, data and modelling techniques. However, these limits are quickly becoming less binding as the data and modelling grow more refined.

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1 According to the results of the Federal Reserve Board's Supervisory Capital Assessment Program, "The estimated two-year cumulative losses on total loans under the more adverse scenario is 9.1% at the 19 participating BHCs [bank holding companies]; for comparison, this two-year rate is higher than during the historical peak loss years of the 1930s" (see http://www.federalreserve.gov/newsevents/press/bcreg/bcreg20090507a1.pdf).

2 Another popular approach to modelling the macroeconomy are dynamic stochastic general equilibrium (DSGE) models. A particularly insightful critique of these models is provided by Robert Solow (see "Building a Science of Economics for the Real World," http://www2.econ.iastate.edu/classes/econ502/tesfatsion/Solow.StateOfMacro.CongressionalTestimony.July2010.pdf).

3 A common criticism of structural models was first articulated by Robert Lucas (see "Econometric Policy Evaluation: A Critique," http://people.bu.edu/rking/REmodels/lucascr.pdf).

4 A good description of VAR models, their advantages and disadvantages is provided by James Stock and Mark Watson (see "Vector Autoregressions," http://faculty.washington.edu/ezivot/econ584/stck_watson_var.pdf). VAR models were first introduced by Christopher Sims, 1980, "Macroeconomics and Reality," *Econometrica*, 48(1), pp 1–48.

5 A thorough description of how the Federal Reserve expects bank holding companies with more than US$50 billion in assets and non-bank financial institutions supervised by the Fed to conduct their idiosyncratic stress tests is provided in "Dodd–Frank Act Mid-Cycle Stress Tests 2013: Summary Instructions," May 2013 (see http://www.federalreserve.gov/newsevents/press/bcreg/bcreg20130513a1.pdf).

5

Determining the Severity of Macroeconomic Stress Scenarios

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In the midst of the 2008 financial panic caused by the collapse of the subprime housing market, the US government responded with unprecedented measures, including liquidity provision through various funding programmes, debt and deposit guarantees and large-scale asset purchases. In February 2009, the US banking supervisors conducted the first ever system-wide stress test on 19 of the largest US bank holding companies (BHCs), known as the Supervisory Capital Assessment Program (SCAP) (Federal Reserve 2009a). The stress test required these 19 BHCs to undergo simultaneous, forward-looking exercises designed to determine whether they would have adequate capital to sustain lending to the economy in the event of an unexpectedly adverse scenario. By conducting this SCAP exercise, the supervisors hoped that it would reduce uncertainty and restore confidence in the US financial institutions. In their 2010 staff reports, Peristian, Morgan and Savino (2010), of the Federal Reserve Bank of New York, concluded that the SCAP might have helped to quell the financial panic by releasing vital information about the BHCs. They claimed, "While investors did not need supervisors to tell them which banks had capital deficiencies, they were surprised by the size of the capital gaps and they used that information to revalue banks."

Since conducting the SCAP in 2009, the Federal Reserve System has conducted annual stress tests on the US banking system, called the Comprehensive Capital Analysis and Review (CCAR). Additionally, the Dodd–Frank Wall Street Reform and Consumer Protection Act requires the Federal Reserve Board to conduct annual stress tests of bank holding companies with total consolidated assets of US$50 billion or more. In each CCAR, the Federal Reserve Board generates an adverse macroeconomic scenario (two adverse scenarios in 2013) and requires BHCs to submit at least one adverse scenario that is related to their own specific portfolios and risk profiles. While the 2013 instructions for CCAR indicate that the adverse scenario developed by the BHC must reflect "a severely adverse economic and financial market environment", it does not specify what should be the "appropriate severity" of an adverse scenario used for the capital planning. This chapter will discuss the severity of the supervisory adverse scenarios and provide a simple methodology to compare the severity of different adverse macroeconomic scenarios. In particular, the key questions we aim to answer are:

- ☐ how to measure the severity of a firm's BHC macro stress scenario;
- ☐ how severe the BHC stress scenario is when compared with the supervisory stress scenarios; and
- ☐ what implications can be drawn about the credibility of the BHC's stress scenario.

THE US SUPERVISORY STRESS SCENARIOS

As part of the Federal Reserve System's CCAR, US domiciled top-tier bank holding companies (BHCs) are required to submit comprehensive capital plans, including *pro forma* capital analyses, based on at least one BHC defined adverse scenario. The adverse scenario is described by quarterly trajectories for key macroeconomic variables (MVs) over the next nine quarters (or longer, as in 2013). In addition, the Federal Reserve generates its own supervisory stress scenarios so that firms are expected to apply both BHC and supervisory stress scenarios to all exposures to estimate potential losses under stressed operating conditions. Separately, firms with significant trading activity are asked to estimate a one-time potential trading-related market and counterparty credit losses under their own BHC scenarios and market stress scenarios provided by the supervisors.[1] For the supervisory stress scenarios, the Federal Reserve provides firms with global market shock components that are one-time, hypothetical shocks to a large set of risk factors. For the last two CCAR exercises, these shocks involved large and sudden changes in asset prices, rates and CDS spreads that mirrored the severe market condition in the second half of 2008.

Since CCAR is a comprehensive assessment of a firm's capital plan, the BHCs are asked to conduct an assessment of the expected uses and sources of capital over a planning horizon. In the 2009 SCAP, firms were asked to submit stress losses over the next two years, on a yearly basis. Since then, the planning horizon has changed to nine quarters. For the last three CCAR exercises, a BHC is asked to submit its *pro forma*, post-stress capital projections in its capital plan beginning with data as of September 30, and spans the nine-quarter planning horizon. The projections begin in the fourth quarter of the current year and conclude at the end of the fourth quarter two years forward. Hence, for defining BHC stress scenarios, firms are asked to project the movements of key macroeconomic variables over the planning horizon of nine quarters. Our analysis on determining the severity of macro stress scenarios is based on the movements of the macroeconomic variables in these nine quarters. As for determining the severity of the global market shock components for trading and counterparty credit losses, it will not be discussed in this chapter because it is a one-time shock and the evaluation will be on the movements of the market risk factors rather than the macroeconomic variables.

In the 2011 CCAR, the Federal Reserve defined the stress supervisory scenario using nine macroeconomic variables: Real GDP, Consumer Price Index (CPI), Real Disposable Personal Income, Unemployment Rate, Three-Month Treasury Bill Rate, 10-Year Treasury Bond Rate, BBB Corporate Rate, Dow Jones Index and National House Price Index (Federal Reserve 2011a). In CCAR 2012, the number of macroeconomic variables that defined the supervisory stress scenario increased to 14. Besides the original nine variables, the added variables were Nominal GDP Growth, Nominal Disposable Income Growth, Mortgage Rate, Market Volatility Index and Commercial Real Estate Price Index (Federal Reserve 2011b). Additionally, there is another set of 12 international macroeconomic variables, three macroeconomic variables and four countries/country blocks, included in the supervisory stress scenario. As for CCAR 2013, the Federal Reserve System uses the same set of variables to define the supervisory adverse scenario (Federal

Reserve 2012) as in 2012. Since the BHCs are required to define their own adverse scenarios of "a severely adverse economic environment", one way to determine the "appropriate severity" of the BHCs' stress scenarios is to compare them with the supervisory adverse scenarios. Although it is stated that the BHC stress scenarios should reflect the BHC's unique vulnerabilities to factors that affect its exposures, activities and risks, by comparing the severity of the BHC's and supervisory stress scenarios we can determine whether the estimates of the losses are consistent with the relative severity of the stress scenarios. For example, if the BHC's own stress scenario is determined to be more severe than the supervisory scenario, but the estimated losses from the supervisory scenario are larger, then we would need to examine the details of the stress loss estimation methodology to determine the causes of this inconsistency.

ALIGNING THE US SUPERVISORY STRESS SCENARIOS

Let us consider the two CCAR supervisory stress scenarios in 2011 and 2012, and the supervisory severely adverse scenario in 2013. By comparing the forecast of the macroeconomic variables over the next nine quarters, we will try to determine which scenarios are the most and least severe.

In general, comparing severity of stress scenarios is relative. That is, we can usually deduce with relative confidence that Scenario A is more severe than Scenario B, but it is much more challenging to quantify how much more severe is Scenario A over Scenario B. In other words, it is much more difficult to define a metric to measure the severity of a stress scenario. Later in this chapter, we will attempt to use a historical event as a reference to give some insights on the measurement of severity.

Before we begin to examine the three supervisory scenarios, we will make the following key assumptions.

- ☐ All scenarios start on the same quarter, Q3 2010, and the projections are over the nine quarters from Q4 2010 to Q4 2012. Hence the scenarios are compared by measuring the change over the nine quarters on the macroeconomic variables.
- ☐ The scenarios are compared on the set of common macroeconomic variables. For example, in 2012 and 2013, the Market

Volatility Index is included in the supervisory stress scenario, but not in 2011, thus this variable is excluded. Therefore, the set of common macroeconomic variables for comparison are all the variables that are defined in the supervisory scenario of 2011 CCAR.

Of the nine macroeconomic variables, Real GDP, CPI, and Real Disposable Personal Income are expressed as growth rates in 2012 and 2013 (see Table 5.1). To convert them back to Real GDP, CPI and Real Disposable Personal Income, we use Equation 5.1 to convert growth rates into actual values, and align all the starting values using the Q3 2010 actual values. For variables such as Unemployment Rate (UR), we first align all the starting values to be Q3 2010, then we use the percentage change over the period (Equation 5.2) to convert the 2012 and 2013 projections to the projections with the same starting values. For example, the Real GDP Growth Rate (Real_GDPGR) is converted to Real GDP (Real_GDP) by the following equation:

$$Real\_GDP_{i+1} = Real\_GDP_i \times \left\{ \left(1 + \frac{Real\_GDPGR_{i+1}}{100} \right)^{0.25} \right\} \qquad (5.1)$$

For other variables, the alignment is just the percentage change over the period,

$$UR\_2011_{i+1} = UR\_2011_i \left(1 + \frac{\left(UR_{2012_{i+1}} - UR_{2012_i} \right)}{UR_{2012_i}} \right) \qquad (5.2)$$

After aligning the supervisory stress scenarios from CCAR 2011, 2012 and 2013, we also create an additional hypothetical stress scenario to illustrate how the severity of stress scenarios can be compared between the supervisory scenarios and a "BHC-developed" stress scenario, as part of the BHC's requirements under CCAR. Table 5.2 shows the three supervisory and the hypothetical scenarios as they are all aligned at Q3 2010. All the scenarios have the same set of macroeconomic variables and they are all aligned to the same value as of Q3 2010. Hence, by comparing the changes of the macroeconomic variables over the next nine quarters, we can examine the severity of each scenario relative to the others.

Table 5.1 The Federal Reserve supervisory adverse scenarios with nine quarters of projections

CCAR 2011 Common variables	**Q3 2010**	**Q4 2010**	**Q1 2011**	**Q2 2011**	**Q3 2011**	**Q4 2011**	**Q1 2012**	**Q2 2012**	**Q3 2012**	**Q4 2012**
Real GDP	13,261	13,332	13,393	13,255	13,206	13,138	13,178	13,229	13,343	13,453
Real Disposable Personal Income	10,237	10,271	10,299	10,318	10,236	10,179	10,081	10,054	10,047	10,066
Unemployment Rate	9.6	9.6	9.6	10.1	10.6	11.0	11.1	11.0	10.9	10.6
CPI	218.0	219.0	219.9	220.9	221.7	222.3	222.9	223.4	224.0	224.7
3-Month Treasury Yield	0.16	0.16	0.19	0.07	0.13	0.13	0.13	0.13	0.13	0.13
10-Year Treasury Yield	2.90	2.57	2.64	2.66	2.79	2.77	2.71	2.98	3.12	3.35
BBB corporate yield	5.07	4.69	4.86	5.88	6.26	6.46	6.16	6.27	6.22	6.25
Dow Jones Total Stock Market Index	11,947	12,069	11,822	9,116	8,809	8,716	10,682	11,083	11,498	11,930
National House Price Index	142	140	139	137	134	132	130	128	127	126

CCAR 2012 Common variables	**Q3 2011**	**Q4 2011**	**Q1 2012**	**Q2 2012**	**Q3 2012**	**Q4 2012**	**Q1 2013**	**Q2 2013**	**Q3 2013**	**Q4 2013**
Real GDP growth	2.46	-4.84	-7.98	-4.23	-3.51	0.00	0.72	2.21	2.32	3.45
Real Disposable Personal Income growth	-1.73	-6.02	-6.81	-4.29	-3.16	-0.57	0.74	1.66	2.69	2.27
Unemployment Rate	9.09	9.68	10.58	11.40	12.16	12.76	13.00	13.05	12.96	12.76
CPI inflation rate	3.09	2.21	1.78	1.02	0.89	0.35	0.23	0.21	0.30	0.32
3-Month Treasury Yield	0.02	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
10-Year Treasury Yield	2.48	2.07	1.94	1.76	1.67	1.76	1.74	1.84	1.98	1.98
BBB corporate yield	4.87	5.65	6.83	6.81	6.75	6.45	6.07	5.83	5.74	5.51
Dow Jones Stock Market Index	11,771.86	9,501.48	7,576.38	7,089.87	5,705.55	5,668.34	6,082.47	6,384.32	7,084.65	7,618.89
National House Price Index	136.86	135.13	131.61	127.50	123.12	119.08	115.15	111.92	109.77	108.48

CCAR 2013 Common variables	**Q3 2012**	**Q4 2012**	**Q1 2013**	**Q2 2013**	**Q3 2013**	**Q4 2013**	**Q1 2014**	**Q2 2014**	**Q3 2014**	**Q4 2014**
Real GDP growth	2.0	-3.5	-6.1	-4.4	-4.2	-1.2	0.0	2.2	2.6	3.8
Real Disposable Personal Income growth	0.8	-3.8	-6.7	-4.6	-3.2	-1.5	0.8	0.9	2.5	2.8
Unemployment Rate	8.1	8.9	10.0	10.7	11.5	11.9	12.0	12.1	12.0	11.9
CPI inflation rate	2.3	1.8	1.4	1.1	1.0	0.3	1.0	0.9	0.7	0.6
3-Month Treasury Yield	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
10-Year Treasury Yield	1.6	1.4	1.2	1.2	1.2	1.2	1.2	1.5	1.7	1.9
BBB corporate yield	4.2	5.6	6.4	6.7	6.8	6.5	6.2	6.2	6.0	5.9
Dow Jones Stock Market Index	14997.8	12105.2	9652.6	9032.8	7269.1	7221.7	7749.3	8133.9	9026.1	9706.7
National House Price Index	143.4	141.6	137.9	133.6	129.0	124.7	120.6	117.2	115.0	113.6

Table 5.2 The macroeconomic variables with nine quarters of projections on the four scenarios

Scenario	CCAR Common variables	Q3 2010	Q4 2010	Q1 2011	Q2 2011	Q3 2011	Q4 2011	Q1 2012	Q2 2012	Q3 2012	Q4 2012
2011	Real GDP	13,261	13,332	13,393	13,255	13,206	13,138	13,178	13,229	13,343	13,453
2012	Real GDP	13,261	13,097	12,828	12,690	12,577	12,577	12,599	12,668	12,741	12,849
2013	Real GDP	13,261	13,143	12,938	12,793	12,657	12,619	12,619	12,687	12,769	12,889
Hypothetical	Real GDP	13,261	12,690	12,690	12,690	12,690	12,690	12,690	12,690	12,690	12,690
2011	Real Disposable Personal Income	10,237	10,271	10,299	10,318	10,236	10,179	10,081	10,054	10,047	10,066
2012	Real Disposable Personal Income	10,237	10,079	9,903	9,795	9,717	9,703	9,721	9,761	9,826	9,881
2013	Real Disposable Personal Income	10,237	10,138	9,964	9,847	9,768	9,731	9,750	9,772	9,832	9,901
Hypothetical	Real Disposable Personal Income	10,237	9,700	9,700	9,700	9,700	9,700	9,700	9,700	9,700	9,700
2011	Unemployment Rate	9.58	9.61	9.62	10.11	10.56	11.02	11.12	11.04	10.87	10.64
2012	Unemployment Rate	9.58	10.20	11.15	12.02	12.82	13.45	13.70	13.75	13.66	13.45
2013	Unemployment Rate	9.58	10.53	11.83	12.66	13.60	14.07	14.19	14.31	14.19	14.07
Hypothetical	Unemployment Rate	9.58	12.66	12.66	12.66	12.66	12.66	12.66	12.66	12.66	12.66
2011	10-Year Treasury Yield	2.90	2.57	2.64	2.66	2.79	2.77	2.71	2.98	3.12	3.35
2012	10-Year Treasury Yield	2.90	2.42	2.27	2.05	1.95	2.05	2.04	2.15	2.31	2.32
2013	10-Year Treasury Yield	2.90	2.54	2.18	2.18	2.18	2.18	*2.18*	*2.72*	*3.08*	*3.44*
Hypothetical	10-Year Treasury Yield	2.90	2.80	2.80	2.80	*2.80*	*2.80*	*2.80*	*2.80*	*2.80*	*2.80*

2011	3-Month Treasury Yield	0.16	0.16	0.19	0.07	0.13	0.13	0.13	0.13	0.13	0.13
2012	3-Month Treasury Yield	0.16	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
2013	3-Month Treasury Yield	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Hypothetical	3-month Treasury yield	0.16	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
2011	BBB corporate yield	5.07	4.69	4.86	5.88	6.26	6.46	6.16	6.27	6.22	6.25
2012	BBB corporate yield	5.07	5.87	7.11	7.09	7.03	6.71	6.31	6.07	5.97	5.73
2013	BBB corporate yield	5.07	6.76	7.73	8.09	8.21	7.85	7.48	7.48	7.24	7.12
Hypothetical	BBB corporate yield	5.07	8.09	8.09	8.09	8.09	8.09	8.09	8.09	8.09	8.09
2011	CPI	218.0	219.0	219.9	220.9	221.7	222.3	222.9	223.4	224.0	224.7
2012	CPI	218.0	219.2	220.2	220.8	221.3	221.4	221.6	221.7	221.9	222.0
2013	CPI	218.0	219.0	219.8	220.4	220.9	221.1	221.6	222.1	222.5	222.9
Hypothetical	CPI	218.0	222.0	222.0	222.0	222.0	222.0	222.0	222.0	222.0	222.0
2011	Dow Jones Stock Market Index	11,947	12,069	11,822	9,116	8,809	8,716	10,682	11,083	11,498	11,930
2012	Dow Jones Stock Market Index	11,947	9,643	7,689	7,195	5,791	5,753	6,173	6,479	7,190	7,732
2013	Dow Jones Stock Market Index	11,947	9,643	7,689	7,195	5,791	5,753	6,173	6,479	7,190	7,732
Hypothetical	Dow Jones Stock Market Index	11,947	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200
2011	National House Price Index	142.4	140.4	139.1	136.8	134.3	131.8	129.6	127.8	126.8	126.4
2012	National House Price Index	142.4	140.6	136.9	132.6	128.1	123.9	119.8	116.4	114.2	112.8
2013	National House Price Index	142.4	140.6	136.9	132.6	128.1	123.8	119.7	116.3	114.2	112.8
Hypothetical	National House Price Index	142.4	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0

HISTORICAL TREND OF THE MACROECONOMIC VARIABLES

In generating the supervisory adverse scenarios, the Federal Reserve emphasises that the scenarios are not economic forecasts, but rather hypothetical scenarios that show significant contraction in economic activities. A contraction in economic activities means macroeconomic indicators such as GDP, employment, stock indexes, investment spending, capacity utilisation, household income, housing prices and inflation fall, while the unemployment rate and personal and corporate bankruptcies rise. Of the nine common macroeconomic variables, the one that is most related to stress economic conditions is a drop in Real GDP. As for the rest of the common variables, most economists would agree that a stress economic condition will associate with a decrease in Real Disposable Personal Income, Dow Jones Index and House Price Index, and an increase in Unemployment Rate. However, for CPI, BBB Corporate Bond Rate, Three-Month Treasury Yield and the 10-Year Treasury Yield, it is not so clear that an increase or decrease in any one of these variables will indicate a stress economic condition.

We will use historical data to examine each of the common variables to understand its relationship with historical recessions. All the historical values are obtained from the Board of Governors' document on Supervisory Scenarios.[2]

In the US, from 1980 to 2013, there have been nine periods of negative economic growth over one fiscal quarter or more (see Figure 5.1). According to the National Bureau of Economic Research (NBER), there have been five periods considered recessions:[3]

- ☐ January 1980–July 1980: 6 months;
- ☐ July 1981–November 1982: 16 months;
- ☐ July 1990–March 1991: 8 months;
- ☐ March 2001–November 2001: 8 months; and
- ☐ December 2007–June 2009: 18 months.

From Figure 5.2, we can see that a drop in GDP Growth Rate is usually associated with a drop in the Real Disposable Personal Income Growth Rate. Thus, we can state, in general, a stress economic condition is associated with a drop in Real Disposable Personal Income Growth.

From Figure 5.3, we can see that the last two recessions are associated with significant drops in the Dow Jones Index, and from Figure

Figure 5.1 US Real GDP growth, 1980–2012

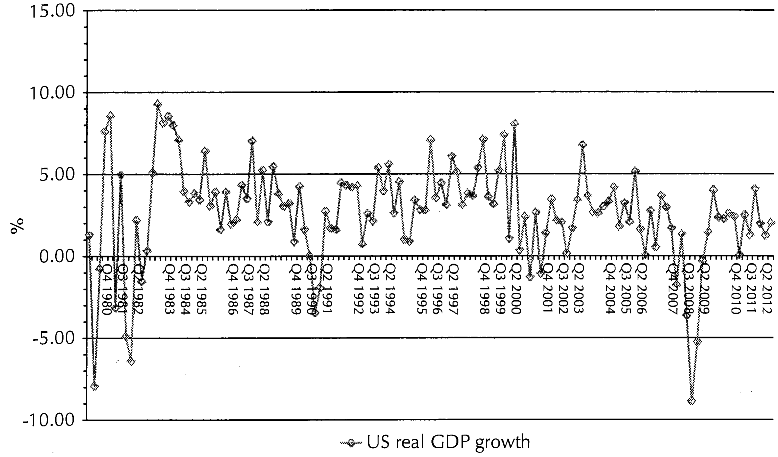
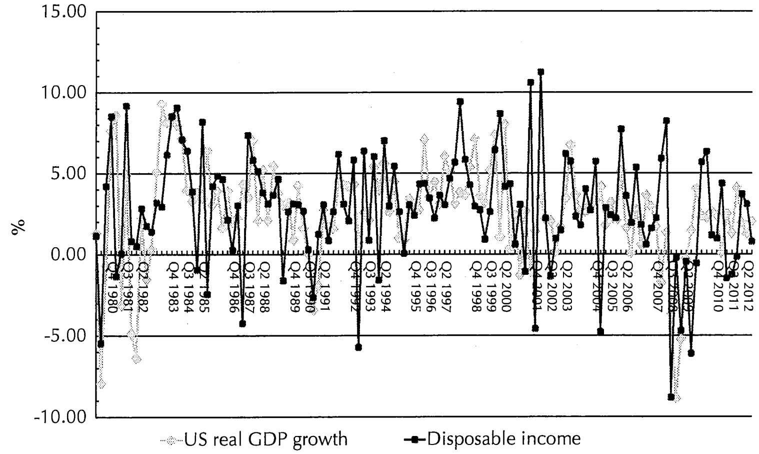


Figure 5.2 US Real GDP growth and income, 1980–2012



5.4 we see that the most severe recession followed a huge drop in the House Price Index. Hence, we can also confidently claim that a stress economic condition is associated with a drop in Dow Jones Index or House Price Index.

Figure 5.5 clearly shows that each recession was associated with a rise in the unemployment rate. However, for BBB Corporate Bond Rate – although for the recessions in 1981 and 2008 we see a high

Figure 5.3 US Real GDP growth and Dow Jones Index

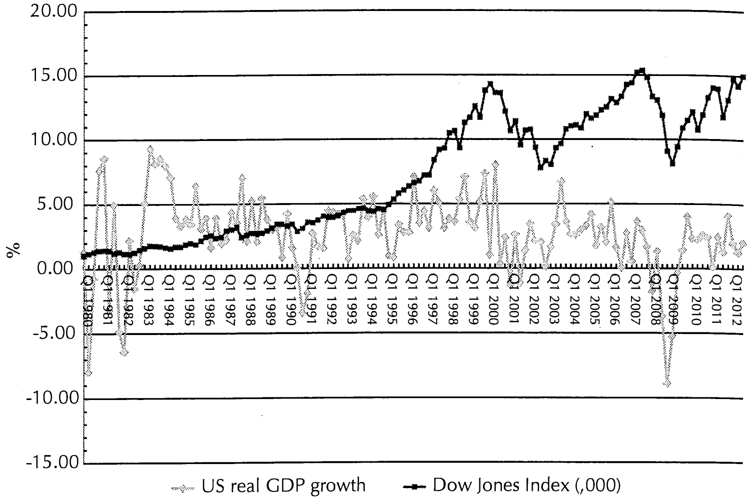
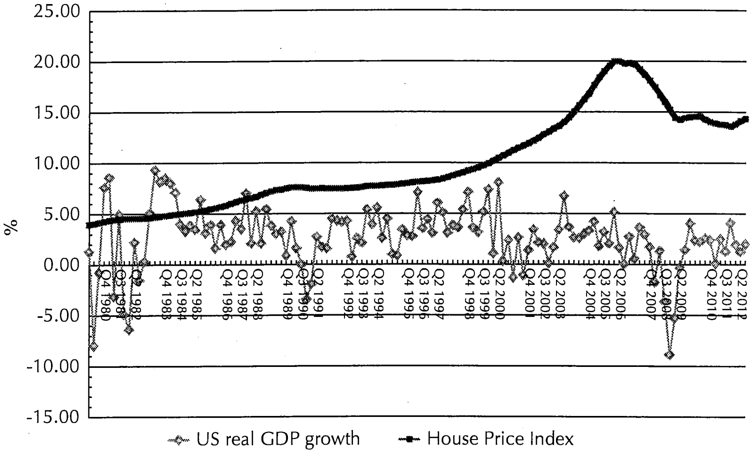


Figure 5.4 US Real GDP growth and House Price Index



increase in the BBB Rate – the rest of the data does not show a high association between GDP Growth Rate and BBB Bond Rate (Figure 5.6).

From Figure 5.7, we see only that a sharp drop in CPI is associated with the last recession, but, for the rest of the historical data, there is

Figure 5.5 US Real GDP growth and unemployment rate

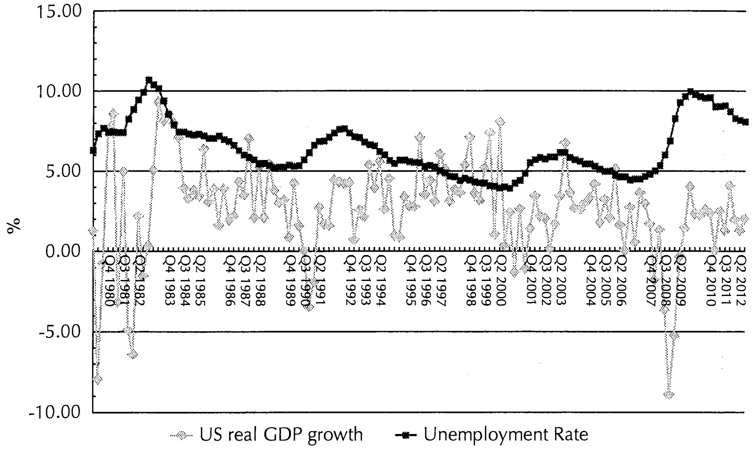
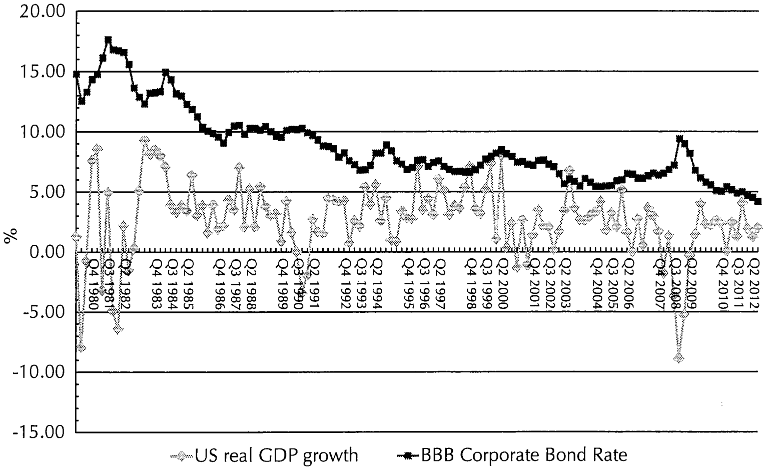


Figure 5.6 US Real GDP growth and BBB bond rate



no obvious association between change in CPI and GDP Growth Rate.

As for the Three-Month Treasury Yield and the US 10-Year Treasury Yield, from Figures 5.8 and 5.9, there is no clear association between Real GDP Growth Rate and Treasury Yields. From examining the historical data, of the nine common macroeconomic variables defined in the stress scenarios we have seen that four of

Figure 5.7 US Real GDP growth and CPI percentage change

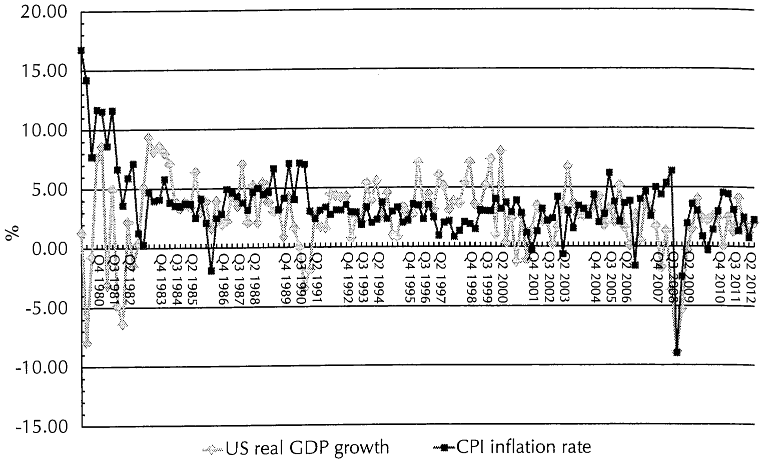
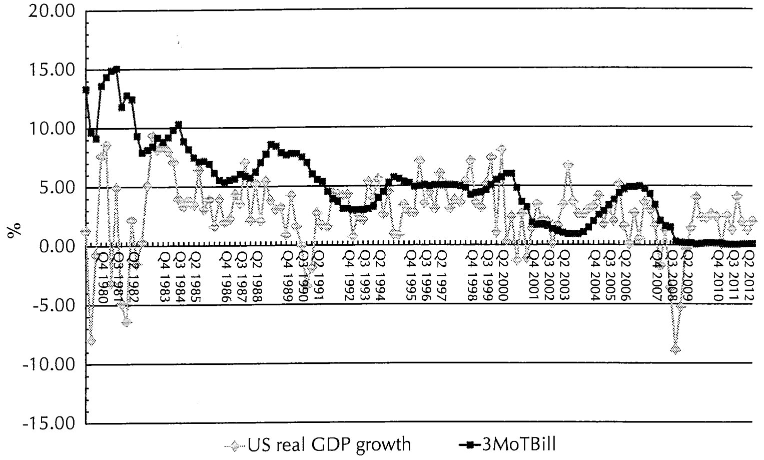
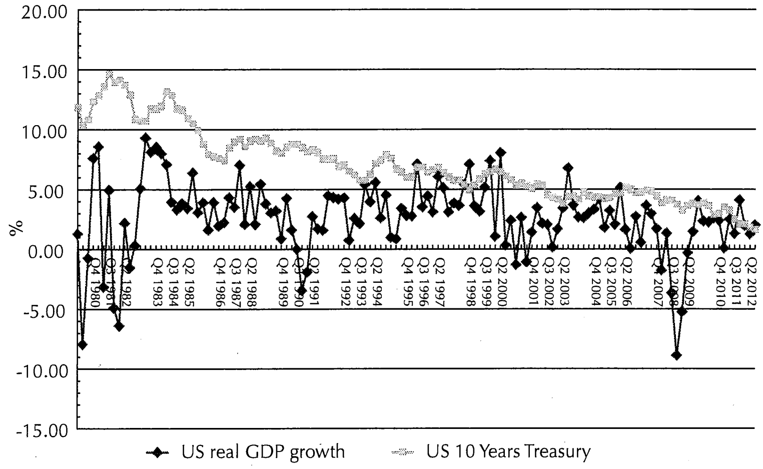


Figure 5.8 US Real GDP Growth and 3 months T bill



them – CPI, Three-Month Treasury Yield, 10-Year Treasury Yield and BBB Corporate Bond Rate – do not show any "directional" indication that either an increase or decrease in value is necessarily associated with a stress economic condition ("directional" means that, if a macroeconomic variable increases in value, then, historically, the economic condition always reacts the same way, either less

Figure 5.9 US Real GDP Growth and US 10-Year Treasury Yield



or more severe in the same direction). Thus, these four variables will not be further considered in our discussion for measuring the severity of a stress scenario.

NINE-QUARTERS PROJECTIONS OF THE MACROECONOMIC VARIABLES

We will now examine the projections of the remaining five macroeconomic variables in each of the four stress scenarios. From Figures 5.10 and 5.11, we can clearly see that the 2011 supervisory scenario is the least severe in terms of GDP and Real Disposable Personal Income. The 2013 scenario follows the same pattern as the 2012 scenario, but the drop at every quarter is only slightly less than that of 2012. As for the Hypothetical portfolio, it has the biggest drop in disposable income. However, the severity in Real GDP is not conclusive because the projected GDP in the Hypothetical are higher than scenarios 2012 and 2013 in some quarters, but lower in other quarters.

We now focus on the next two "directional" macroeconomic variables: Dow Jones Index and House Price Index. From Figures 5.12 and 5.13, we can see that scenarios 2012 and 2013 are exactly the same. The three supervisory scenarios follow similar patterns. On the Dow Jones Index, there is a sharp drop in the beginning, followed

Figure 5.10 Projections of the four scenarios – Real GDP

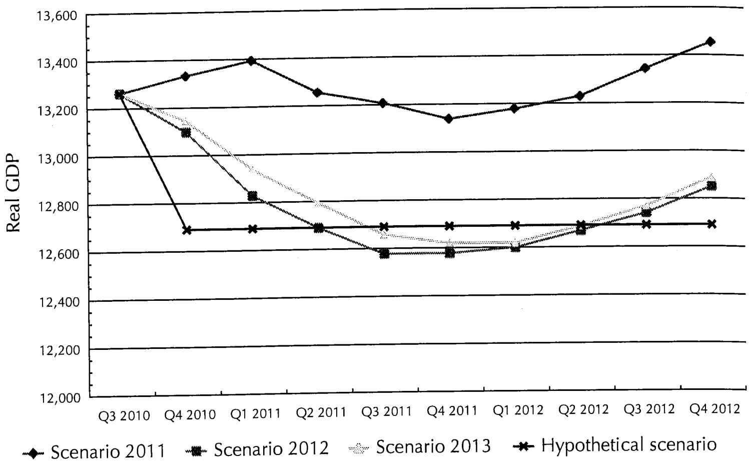
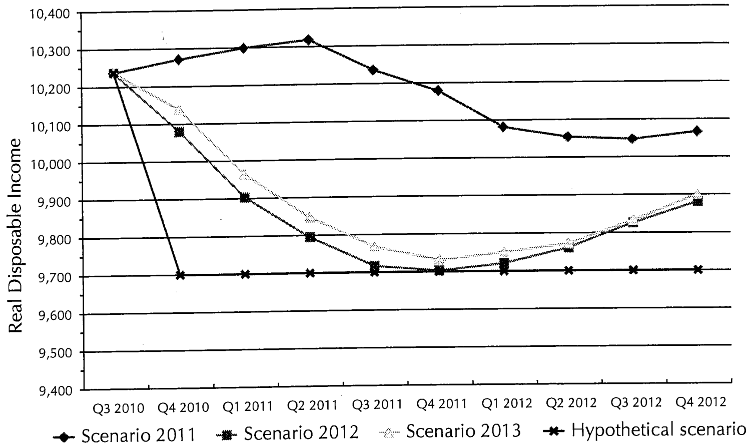


Figure 5.11 Projections – Real Disposable Personal Income



by an increase after the fourth quarter, and scenario 2011 shows that the drop is the mildest. As for the House Price Index, the projections are all declining quarter after quarter, and the decline in scenario 2011 is also the mildest. Since the Hypothetical cut across the curve of scenarios 2012 and 2013, by examining the charts, apart from scenario 2011, it is not conclusive which one is the most severe scenario.

Figure 5.12 Projections – Dow Jones Index

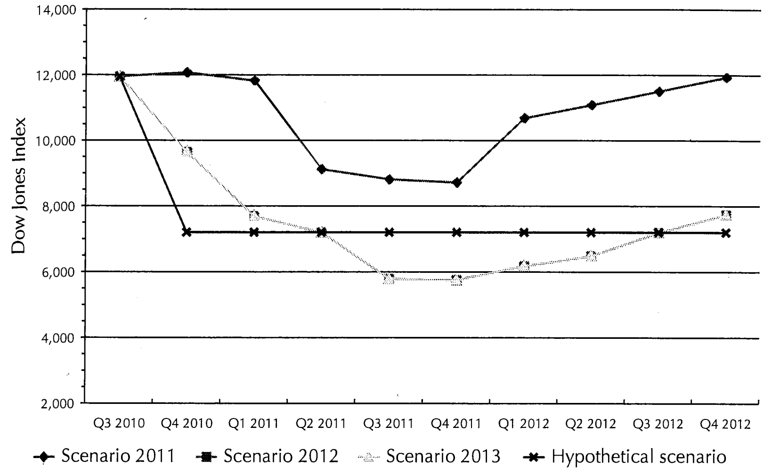
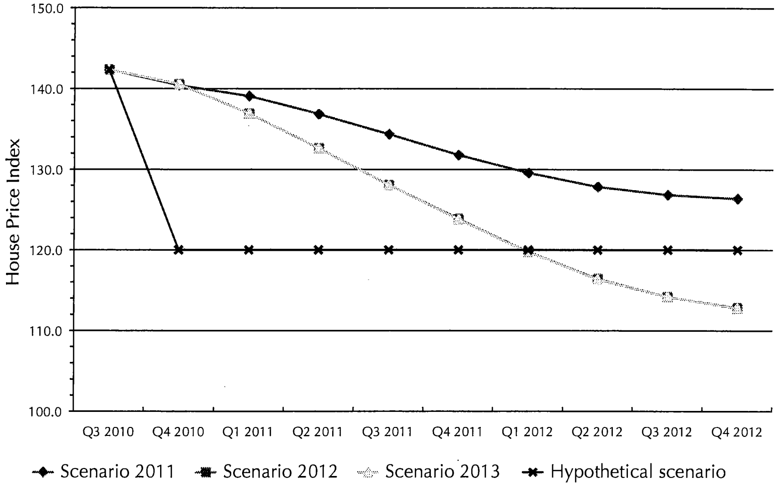
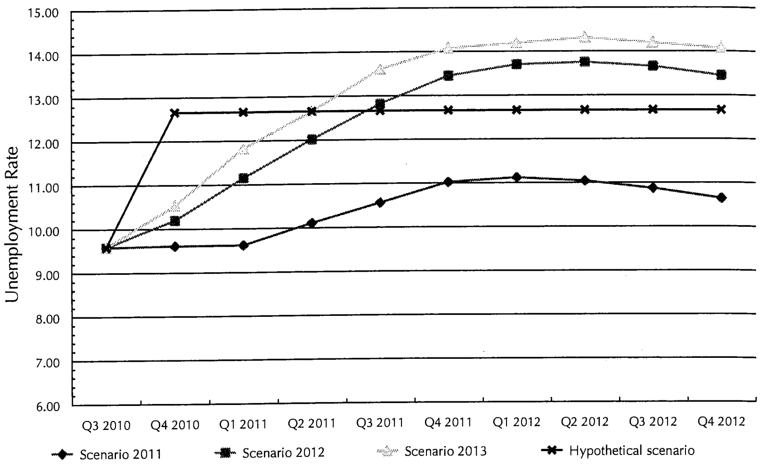


Figure 5.13 Projections – House Price Index



Finally, on examining the Unemployment Rate (Figure 5.14), we see that the three supervisory scenarios all project that the unemployment rate will go up over the next six quarters, then plateau, and finally drop slightly at the end. It is also obvious that scenario 2011 is the mildest, and it is inconclusive between the Hypothetical scenario and scenarios 2012 and 2013. By now, we have established that for

Figure 5.14 Projections – Unemployment Rate

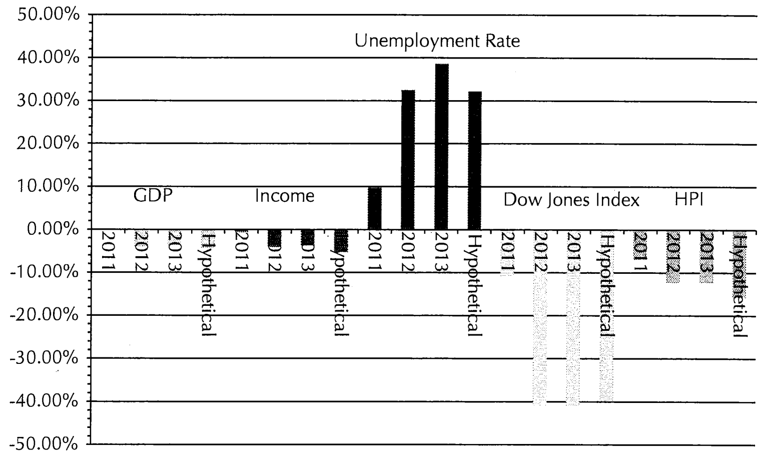


the three supervisory scenarios – since each of the variables we have seen follows the same pattern, on the whole – scenario 2011 is the mildest, and scenario 2012 and 2013 are almost the same except that scenario 2012 is slightly more severe.

When comparing the Hypothetical scenario with the 2012 and 2013 scenarios in Unemployment Rate, there are some quarters in which the hypothetical scenario has the higher Unemployment Rate, and some quarters in which the 2012 and 2013 scenarios have the higher Unemployment Rate. Therefore, in order to make an overall comparison, it is necessary to develop a statistic to summarise, measure and standardise the severity of each variable over the nine quarters.

Since we have aligned all the scenarios to the same starting point, the severity of each quarter is determined by the percentage change with respect to the starting quarter (Q3 2010). Thus, a probable summary statistic is the average of the percentage change with respect to the starting quarter. Another choice is the maximum change over the nine quarters, but the maximum value ignores the projections with recovery at the end of the nine quarters. The average of the percentage change is computed by Equation 5.3 below, where i is the index for the four scenarios, and j is the index for each of the projections.

Figure 5.15 Average change in macroeconomic variables from Q3 2010



$$Ave\ \%\ Change\ UR_i = \sum_{j=1}^{9} \frac{100}{9} \left(\frac{\left(UR_{i,j} - UR_{i,3Q2010}\right)}{UR_{i,3Q2010}} \right) \tag{5.3}$$

This summary statistic can be computed for the five "directional" macroeconomic variables in each scenario. We now have a measure to compare the severity of the scenarios on each of the variables independently of the other variables. From Figure 5.15, we can see that the longer the vertical bar is away from zero, the more severity it indicates. Thus, for Unemployment Rate, the longest bar is in 2013, which means the most severe scenario is 2013. For GDP, Disposable Income, and HPI, the Hypothetical scenario is the most severe. For Dow Jones Index, the 2012, 2013 and Hypothetical scenarios are more or less the same. Viewing across the chart, we see that the 2011 scenario is the least severe in each of the five variables.

In terms of the magnitude of severity, we see that Unemployment Rate and Dow Jones Index have 30% to 40% average deterioration in scenarios 2012, 2013 and the Hypothetical, whereas the other variables are much less severe. Hence, we have a measurement of severity for each macroeconomic variable. In the next section, we will suggest some ways to combine all these measurements to give an overall view of the severity of a stress scenario.

AN OVERALL ASSESSMENT OF THE SEVERITY

At the start of our discussion, we mentioned that measuring severity is, in general, relative. However, some economists (Edge 2012) have tried to use historical recessions as anchors, and relate the stress scenarios to historical recessions to get some sense of magnitude as compared with past recessions. We will discuss other methodologies in more detail in the next section. For now, we will propose a simple methodology to summarise the severity of each scenario with reference to a historical recession.

For each macroeconomic variable, we have four scenarios. We will use an ordinal ranking to assign a rank to each of the scenario by using the Average % Change, giving rankings of 1–4 to indicate least to most severity. When the Average % Change shows that two scenarios are very similar (within 1% of each other), we assign the average of the two ranks to both scenarios. Since severity in Unemployment Rate is associated with increasing value, the lowest rank is given to the lowest Average % Change. Table 5.3 gives the ranking of each variable and the total ranking. By summing across the rank of each variable, we arrive at a statistic that gives an overall ranking (Total Rank) of the scenarios. With this simple methodology, we have determined the severity of the four macro stress scenarios. In order of severity, the most severe scenario is Hypothetical, followed by 2013, 2012 and 2011. However, on further examination, the differences in Total Rank between the Hypothetical, 2013 and 2012 scenarios are not that significant (<20%), hence these three scenarios are comparable in terms of severity.

Since all these four scenarios are hypothetical forward-looking scenarios, and we now have some understanding of the severity among them, the next logical question should be how they are related to our historical experience. Looking back at the past postwar recessions, we see that the most severe recession is the 2008 Recession (December 2007 to June 2009), which lasted 18 months. In order to align with the nine projected quarters of our scenarios, we will use the NBER data and choose the consecutive nine quarters of Real GDP Growth Rate when the recession began in the first quarter of 2008. After aligning for Q3 2010 as the starting quarter and the conversion of the values as described in the last section on the remaining nine quarters, we have the similar values on the macroeconomic variables for comparison in Table 5.4. The first column has the actual values as

Table 5.3 Ranking of each macroeconomic variable and the total rank of the scenario

	Real GDP		Disposable Income		Unemployment Rate		Dow Jones		HPI		
Scenario	**Ave % change**	**RANK**	**Ave % change**	**RANK**	**Ave % change**	**RANK**	**Ave % change**	**RANK**	**Ave % change**	**RANK**	**Total**
2011	0.2	1	-0.6	1	9.7	1	-11.0	1	-6.88	1	5.0
2012	-4.0	3	-4.1	2.5	32.4	2.5	-40.8	3	-12.2	2.5	13.5
2013	-3.5	3	-3.7	2.5	38.5	4	-40.8	3	-12.2	2.5	15.0
Hypothetical	-4.3	3	-5.2	4	32.2	2.5	-39.7	3	-15.7	4	16.5

Table 5.4 Nine-quarters values of changes for 2008 Recession[4]

Common Variables	**Q3 2010**	**Q1 2008**	**Q2 2008**	**Q3 2008**	**Q4 2008**	**Q1 2009**	**Q2 2009**	**Q3 2009**	**Q4 2009**	**Q1 2010**
Real GDP	13,261	13,202	13,245	13,122	12,820	12,649	12,639	12,684	12,810	12,884
Real Disposable Personal Income	10,237	10,385	10,592	10,350	10,344	10,220	10,208	10,048	10,033	10,172
Unemployment Rate	9.58	9.98	10.64	11.98	13.70	16.50	18.49	19.23	19.83	19.49
Dow Jones Index	11,947	10,748	10,540	9,574	7,326	6,541	7,598	8,797	9,269	9,804
House Price Index	142	137	131	126	120	114	112	113	114	115

in Q3 2010. This is used as the anchor to align all the scenarios that have the same starting values. The rest of the nine columns are from Q1 2008 to Q1 2010 (projections of nine quarters as in all supervisory scenarios). The values in these nine columns are scaled to the starting values of the first column, and so the 2008 Recession values start from the second column.

After we calculate the average percentage change of the five variables over the nine quarters, we find that the Average % Change on Real Disposable Personal Income is slightly positive (0.2%). Thus, during the 2008 Recession, the Real Disposable Personal Income is not "directional", as we once thought. We have come to realise that it is not necessarily true that Real Disposable Personal Income will decrease in a severe stress economic condition, especially when we are looking at the overall change in nine quarters. Therefore, including the Real Disposable Personal Income will taint our measurement of severity. Hence we will drop the Real Disposable Personal Income from our ranking on the overall severity. We can now put the Average % Change of the rest of the variables back into the ranking methodology and observe the ranking of the recession with other scenarios.

From Table 5.5, we observe that the 2008 Recession is ranked as the most severe, followed by Hypothetical, 2013, 2012 and 2011. However, apart from the unemployment rate in the 2008 Recession, the differences among the four most stressful scenarios are not so significant that they can be easily separated. In fact, for the Dow Jones Index, the 2008 Recession is the second least severe of the five scenarios. Hence we conclude that the Hypothetical, 2012 and 2013 scenarios have similar severity to the 2008 Recession.

In all our discussions so far, we have assumed that all the directional variables are of the same importance, hence we have not assigned different weights when aggregating the ranks of each variable. However, we know different macroeconomic variables will affect different banking institutions. For example, banks with large credit-card portfolios are more sensitive to the unemployment rate; banks with large mortgage portfolios are more sensitive to house prices; and banks with large corporate portfolios are more sensitive to real GDP and equity indexes. In addition, the severity of the loss is related to the credit quality of the portfolio. Thus, the severity of the stress scenario also depends on the risk profile and the businesses of

Table 5.5 Ranking of each macroeconomic variable and the total rank of the scenario and recession

	Real GDP		Unemployment Rate		Dow Jones		HPI		
Scenario	**Ave % change**	**RANK**	**Ave % change**	**RANK**	**Ave % change**	**RANK**	**Ave % change**	**RANK**	**Total rank**
2011	0.2	1	9.7	1	-11.0	1	-6.88	1	4.0
2012	-4.0	3.5	32.4	2.5	-40.8	4	-12.2	2.5	12.5
2013	-3.5	3.5	38.5	4	-40.8	4	-12.2	2.5	14.0
Hypothetical	-4.3	3.5	32.2	2.5	-39.7	4	-15.7	4.5	14.5
08 Recession	-2.8	3.5	62.2	5	-25.4	2	-15.5	4.5	15.0

PANEL 5.1 CASE STUDY: BANCO DE ESPAÑA STRESS SCENARIO

In this chapter, we have demonstrated the use of a simple method to assess the relative severity of a stress macroeconomic scenario. To illustrate how simple that methodology is, let us try to assess the severity of the stress-test exercise (Wyman 2012) that was conducted by Oliver Wyman in 2012 on behalf of the Banco de España. Page 83 of the report describes the adverse scenario with eight macroeconomic variables, and four of them, Real GDP, Unemployment Rate, Housing Prices and Madrid Stock Exchange Index, are similar to the variables we have studied. After aligning the starting values, the average percentage change over the two-year periods for the four variables are, Real GDP –5.1%, Unemployment Rate 19.9%, Madrid Stock Exchange Index –52.5% and Housing Prices –21.7%. Compared with the scenarios in Table 5.5, except for the Unemployment Rate, the other three variables are the most extreme among all the scenarios examined. If we use the ranking assignment as above, this adverse scenario is the most severe among all the six scenarios.

However, comparing the severity of these scenarios this way is not without problems. First, there is no reason to assume that the macroeconomic variables will affect the economies of Spain and the US in the same way. In addition, Spain's unemployment rate is already at 21.6% to begin with, and 21.6% is double what we saw in the 2008 Recession. We can say Spain is already under an economic stress that we have not seen in the US since the Great Depression. Thus, we face additional challenges when comparing scenarios across different countries with different starting values on the macroeconomic variables.

a bank. Based on the bank's experience, different weights can be assigned to different variables to emphasise the importance of certain variables.

OTHER METHODOLOGIES OF MEASURING SEVERITY

Our approach to assessing severity is entirely ordinal and so the relative ranks do not reflect anything about the magnitudes of the average percentage change, or the degree of severities. Ranking the scenarios will necessarily give some scenarios high rankings even if all the scenarios are quite mild, and some scenarios low rankings even if all the scenarios are quite severe. As we saw earlier, our approach is to give relative ranking to the scenarios under consideration. By comparing the scenarios with the 2008 Recession, we have attempted to give the four scenarios a reference point besides comparing them with each other.

There have been other attempts to quantify the severity of stress scenarios. One of them is to determine the probability of occurrence of a stress (or worst) scenario. The general belief is that the less likelihood there is of an occurrence of a stress scenario, the more severe the stress scenario will be. In the 2009 SCAP exercise, in Footnotes 3 and 4 of Federal Reserve (2009b), the supervisors attempted to assign a probability of occurrence to the adverse scenario by claiming that "the likelihood that the average unemployment rate in 2010 could be at least as high as in the alternative more adverse scenario is roughly 10 percent. In addition, the subjective probability assessments ... imply a roughly 15 percent chance that real GDP growth could be at least as low, and unemployment at least as high ... [and] there is roughly a 10 percent probability that house prices will be 10 percent lower than in the baseline by 2010". Another example appears in an article on Economy.com in which Ed Friedman (2012) assigned probabilities to the Fed's 2013 CCAR scenarios. He first put the probability for each baseline scenario at around 50%. Then he claimed, "The Fed's Severely Adverse scenario is comparable to one that Moody's Analytics terms S4. We currently see a 4% chance that this scenario will occur. The Fed's Adverse scenario is more puzzling ... we believe [it] has about a 10% chance of occurring." It seems to us that most of this assigning of probabilities is based on judgement rather than any empirical derivation.

One of the more interesting approaches to quantifying severity is proposed by two Federal Reserve Board economists, Rochelle Edge and Sam Rosen. Their simple approach (2012) is for each scenario, they will score the Average % Change of the common variables by assigning a value of 100 to the variable if the deterioration in the variable equals what occurred in the 2008 Recession (most severe), and by assigning a value of 0 to the variable if the deterioration equals what occurred on the average in the two recessions (mild recessions) before the 2008 Recession. Below, we use a modified version of their approach to illustrate how severity can be quantified.

For each common variable in the 2008 Recession, we assign a score of 100 for the Average % Change, and 0 if the Average % Change is 0. In addition, we cap the score of each variable at 100 and assign a floor of 0. We then use a simple linear interpolation to convert each vari-

Table 5.6 Score of each macroeconomic variable and the average score of the scenario and recession

	Real GDP		Unemployment rate		Dow Jones		HPI		
Scenario	**Ave % change**	**Score**	**Ave % change**	**Score**	**Ave % change**	**Score**	**Ave % change**	**Score**	**Average score**
2011	0.2	0	9.7	16	-11.0	43	-6.88	44	26
2012	-4.0	100	32.4	52	-40.8	100	-12.2	78	83
2013	-3.5	100	38.5	62	-40.8	100	-12.2	78	85
Hypothetical	-4.3	100	32.2	52	-39.7	100	-15.7	100	88
08 Recession	-2.8	100	62.2	100	-25.4	100	-15.5	100	100

able of a scenario into a score. For example, the Average % Change in UR in the 2008 Recession is 62.3%, and in Scenario 2013 is 38.5%. Thus the score for the 2008 Recession in UR is 100, and for Scenario 2013 is given by the following equation:

$$Score\_2013_{UR} = 100\left(1+\frac{(38.5-62.2)}{62.2}\right) = 62 \tag{5.4}$$

Table 5.6 gives the results of the scoring approach. Using the 2008 Recession as a reference point, Scenario Hypothetical, 2013 and 2012 are very similar to and a bit less severe than the 2008 Recession. The 2011 scenario is the mildest and its average score is quite different from the rest. Although our choices in this approach are sometimes arbitrary, nonetheless the approach is intuitive and informative, and gives a good sense of how the scenarios are compared.

So far, the approaches we have discussed do not assume any correlations among the four common macroeconomic variables. The overall assessment is made by summing each variable independently. A statistical approach proposed by Debashish Sarkar (2012) attempted to solve the major problems of the aggregating of information across different variables and across time. He suggested using the Mahalanobis distance to solve these problems with a set of weights. The distance, D, is defined by the following equation:

$$D = \sqrt{(x-\mu)' W^{-1}(x-\mu)} \tag{5.5}$$

In the formula, X is a vector that stacks different variables in a scenario through time. The vector μ stacks the same variables for a reference scenario. The matrix W collects the weights. This approach is to construct W based on the variance–covariance matrix of the out-of-sample forecast errors. While the main challenge of this approach is that the distance measure is not directional, it is also very sensitive to the choice of W and the reference scenario. Sarkar's results showed that this approach is best used in conjunction with some other methods and is more efficient for identifying outlier/problem scenarios. Similarly, in a somewhat related paper, Breuer *et al* (2009) also suggested using the Mahalanobis distance to quantify the plausibility of a severe stress scenario.

Lastly, we mention another approach that aggregates the information in different macroeconomic variables through a simple forecasting framework. In their 2012 paper, Guerrieri and Welch (2012) derived several forecasting models to predict some key metrics that measure the "health" of a bank holding company. The key metrics that they wanted to forecast were: net charge-offs on loans and leases, pre-provision net revenue (PPNR), net interest margin (NIM) and the Tier 1 regulatory capital ratio. The forecast is based on a set of macroeconomic variables: Real GDP Growth, Unemployment Rate, the growth rate of the national house price index, the term spread, the growth rate of the S&P 500 index, the implied volatility of the S&P 500 index options, and the real interest rate. For each macroeconomic variable V_i and for each key banking metric, C, they used a simple (lag) regression that takes the form:

$$C_t = \alpha + \beta C_{t-1} + \gamma_1 V_{t-1}^i + \gamma_2 V_{t-2}^i + \gamma_3 V_{t-3}^i + \gamma_4 V_{t-4}^i + u_t \tag{5.6}$$

They used the Consolidated Reports of Condition and Income (Call Report) of the Federal Deposit Insurance Corporation to develop their forecasting models. By applying the historical information from the Call Report data and the changes in the macroeconomic variables in the stress scenarios to the forecasting models, we can obtain the forecast estimates of the key metrics. Consequently, we can then use the results, eg, average forecast charge-offs, to quantify the severity of the scenarios. The usefulness of this approach depends highly on the accuracy of the forecasting models, especially on the later forecasting quarters. However, Guerrieri and Welch found large root-mean-square errors for the forecasts of all the metrics, and their best-performing model did not beat a random walk at all horizons for forecasting pre-provision net income.

CONCLUSION

Our approach is based on examining the extremities of each of the directional variables, and adding up the extremities without considering the correlation and the timing of the macroeconomic variables. We have avoided trying to quantify the severity and used ordinal ranking to smooth out the "noises" of the variations. There is no error estimate in our assessment, nor do we give any confidence levels on our assessment: there is a danger of pseudo-accuracy when we try to find precision, and precision is difficult to define. It is exceptionally difficult to validate a model to assess the severity of a stress scenario. In the previous section, we mention that

Economy.com states that the 2013 Fed Severely Adverse scenario has a 4% chance that it will occur. The interesting question is why it is 4% and not 10%? The figure seems arbitrary. No one will dispute that the 2008 Recession is the most stressful economic period since the Great Depression. Using the 2008 Recession as a severe stress scenario, someone might say it is a 1-in-80-year event because it is the most severe recession for 80 years. However, if another recession as severe as or more severe than the 2008 Recession happens in the next 10 years after 2008, then it reduces the occurrence of such a severe event to a 1-in-45-year event. Thus, it is quite difficult to quantify such a rare event with certainty because any occurrence of a similar event in the future will render the estimate to be inaccurate.

One of the principles of stress testing listed in the 2009 BIS (BIS BCBS 2009) paper is, "Stress tests should feature a range of severities, including events capable of generating the most damage whether through size of loss or through loss of reputation." The challenge is how to define an event that will generate the most damage to a bank. In their paper, Borio, Drehmann and Tsatsaronis (2012) concluded that "stress tests failed spectacularly when they were needed most: none of them helped to detect the vulnerabilities in the financial system ahead of the recent financial crisis". To improve the performance of macro stress tests, they suggested increasing the severity of the scenarios. The financial crisis of 2008 can be used as a starting point to gauge the severity of a bank's stress scenario. According to the above 2009 BIS paper, "prior to the (2008) crisis, however, banks generally applied only moderate scenarios, either in terms of severity or the degree of interaction across portfolios or risk types … Scenarios that were considered extreme or innovative were often regarded as implausible by the board and senior management."

Have the banks learned their lessons? Are they designing severe stress scenarios that will result in estimates of losses that show their vulnerabilities? In this chapter, we have suggested a simple way to answer these questions, and discussed alternate methodologies to answer the same questions. In many countries, banking regulators are requiring banks to perform stress testing on an annual basis. As more data is gathered from these exercises, it will enhance further research on this topic, and hopefully the macro stress tests will become a valuable tool in the banks' risk-management arsenal.

1 In 2013, six US BHCs were subject to estimate trading losses: Bank of America Corp, Citigroup, Goldman Sachs, JPMorgan Chase, Morgan Stanley and Wells Fargo & Co.

2 Historical Data: 1976 through Second Quarter 2012--October 9, 2012 (Excel) – available for download at http://www.federalreserve.gov/bankinforeg/ccar.htm.

3 See http://www.nber.org/cycles.html.

4 The nine quarters from Q1 2008 to Q1 2010 are converted to Q3 2010 as the starting values.

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6

Data, Analytics and Reporting Requirements: Challenges and Solutions

John P. Haley and Thomas Day

Regions and Moody's

The 2007–09 financial crisis highlighted the difficulty, and at the same time the importance, of ensuring banks have adequate capital for economic downturns. In the wake of the 2009 Supervisory Capital Assessment Program (SCAP) report and throughout the Comprehensive Capital Analysis and Review (CCAR) 2011–13 cycles, the majority of the stress-testing effort went into enhancing analytical modelling. However, the focus has shifted toward making the process sustainable, repeatable and resilient. This chapter will discuss the implications this shift in focus has for data – not only its capture, but its governance and how to make it accessible to multiple constituents. Although technology will be an important part of the solution, it will also require re-thinking basic business processes. Additionally, to gain the full value of this investment, even the interaction with the customer must change. Data governance, quality and capture will need to be considered at earlier stages of the data supply chain, beginning as early as the point of risk origination. Banks are in the business of taking risk – any insight that improves their ability to make those decisions will lead to a competitive advantage.

In this chapter, we first provide a background to stress testing and discuss technology and infrastructure challenges. We also summarise various costs and benefits of improved data management, and the challenges presented by various regulatory and supervisory requirements. Next, we will cover data governance issues, the data requirements to meet US stress-testing mandates and the basic elements of a sound data management infrastructure. We will also discuss some of the workflow challenges that may require firms to rethink existing business processes, and provide a practical example involving how banks think about and plan new business actions over a forecast horizon. Last, we will profile a stylised system integration for a systemically important financial institution (SIFI), explore how the new requirements will impact customers and conclude with some thoughts on the road ahead.

BACKGROUND TO THE FEDERAL RESERVE'S CCAR STRESS-TESTING PROCESS

During the financial crisis, regulators and many of the banks were flying blind. Data and information from the banks were not always available in a timely fashion, and decisions needed to be made on the fly. Many banks were unable to create risk and financial impact reports that properly described their positions and exposures. The ability of the banks and regulators to identify, measure and understand potential losses, and consequently the adequacy of loss-absorbing capital, was absent. One of the most significant reasons for this problem was the often-fractured nature of existing information systems, with data living in what might be called data silos.

Whether due to the distractions of mergers and acquisitions, growth into new products and markets, diverse and disconnected systems and processes, or being lulled into a false sense of comfort by the lack of significant volatility over the preceding 20 years (ie, the "Great Moderation"), management was unwilling to invest in more comprehensive and integrated risk infrastructure. As a result, neither banks nor their regulators were able to quantify risk exposures and communicate possible consequences of emerging trends.

As the memory of the financial crisis begins to fade, firms run the risk of falling into a sense of complacency, particularly with regard to the investments required to create a more agile and risk-aware organisation: an organisation that is able to react quickly in the face of systemic or idiosyncratic shocks. The clear desire is that banks that are able to identify and mitigate risks, as expected or even unexpected forecasted conditions change, will be at a competitive advantage to those firms that are focused only on the compliance aspects of stress testing. Such banks are able to improve their planning regarding asset-mix decisions; enhance business strategy around products, geographies and industries; determine the right mix of funding and capital choices; and better determine performance under a variety of potential future conditions, not merely stressed conditions.

The crisis also revealed that much of the banking industry was undercapitalised, or supported by lower quality capital, and unprepared for a protracted systemic stress that strained or eliminated the firm's capital and liquidity formation capabilities. Many banks had made large capital distributions to shareholders, repurchased stock to boost returns-on-equity, increased leverage, kept unencumbered liquid assets to a bare minimum and paid large levels of compensation to senior executives without evaluating the quality, composition and access to capital under adverse conditions. This resulted in a protracted period of higher leverage, including hidden leverage by way of off-balance-sheet exposures, and a significant underestimation of the level and degree of asset volatility, and associated liquidity and funding risks. As the crisis continued, many banks were no longer able to fulfil their role as credit intermediaries during the stress period, creating a fragile and highly procyclical financial system.

In 2009, the regulatory community sought to ensure that the largest banks in the US had adequate capital to survive a continuation of the economic downturn through SCAP. This massive exercise was the first time the regulators, and many of the banks, had attempted to quantify their exposure through a comprehensive, industry-wide stress test. To support the process, the banks had to submit data on each of their portfolios. Given the timing of the request, the majority of the data was supplied using *ad hoc* extraction reports on spreadsheet templates. It was autumn 2011 before the Federal Reserve Board (FRB) implemented the quarterly data collection templates, and June 2012 before it implemented the monthly template.

In the wake of the SCAP report and throughout the CCAR 2012 and 2013 cycle, the majority of the stress-testing effort went into enhancing analytical modelling techniques relating to loss estimation under various economic scenarios, and ensuring that banks would have enough capital, under a severe stress, to maintain at least a 5% Tier 1 common capital ratio across the forecasted planning horizon.

Now the focus is shifting toward other areas of the stress-testing programme, including an intense focus on internal governance processes; increased automation; a focus on supporting business processes and infrastructure; model validation and documentation; sensitivity analysis and other areas of the measurement methods. These include significantly improved pre-provision net revenue (PPNR) modelling, non-interest income and expense modelling, and the quality of forecasted risk-weighted assets (RWAs).

POST-CRISIS INFRASTRUCTURE CHALLENGES

In many organisations, the state of technology architecture is a significant challenge. It is not uncommon that core loan accounting systems, while feeding a central enterprise data warehouse (EDW), do not possess all of the data, or analytical and bespoke service resources, required for stress testing or regulatory reporting. As mentioned elsewhere in this chapter, the data is spread across numerous legacy systems, and in some cases required data may even be held in spreadsheets and other documents, or simply be missing.

The first step in attacking the data challenge is to inventory all of the feeder systems that are necessary to populate the required regulatory reports. To perform this task, the regulatory reporting, compliance, IT and risk management groups must define the critical data sources and gaps. Although not all data can be immediately remediated, it is important that the data gaps are prioritised and resolved in a timely fashion. Within the context of the CCAR exercise, this is important not only for the bank, but to evidence to the supervisory authorities the project plan to enhance overall data governance. The data remediation is most efficiently carried out via internal resources, often the firm's internal audit and loan review functions, with data resolution templates being passed from these groups back to loan operations for data augmentation and improvement. Key performance indicators (KPIs) are usually required to measure progress, and report on it to senior management, the board and the supervisory authorities.

LEGACY DATA CHALLENGES AND QUALITY

The implications of capturing, storing and transmitting this data on processes and systems are easy to understand. Perhaps what is less obvious is that even some of the data fields that might have been collected for years have never been subjected to much scrutiny, and the quality and consistency of the data will therefore be suspect. This data can be categorised into four different types.

- ☐ Data supporting financial statements, such as loan amounts, interest rates and maturities, have long been subject to strong input controls, routine quality assurance monitoring and regular independent review. This information also has been maintained on legacy accounting systems for many years, and was required to be re-validated upon merger or conversions.
- ☐ Data supporting origination decisions, such as collateral value and underlying obligor financial data, have also been subject to the same strong controls, monitoring and independent review. However, this information was not necessarily stored electronically. Even if stored on the origination system, it may not have been passed on to legacy accounting systems and not required to be maintained upon merger or conversions.
- ☐ Data supporting the servicing process, such as payment terms or addresses, are subject to less stringent input controls and probably have not been subjected to the same quality assurance or independent reviews. However, through the servicing process, the information will generally receive routine validation with the customer. Also, this information is maintained on the legacy accounting system through mergers and conversions.
- ☐ Other indicative data, such as property size, performance of junior liens owned by others and the industry code, may or may not have been collected in the past. Even if collected, these have been subject to very little of the above oversight.

Table 6.1 summarises the relative value of these four different types of data by the factors that affect either the quality or the availability of data. Indicative data will have a low level of reliability and will be difficult to rely on in modelling or capital planning. In contrast, data supporting the financial statements should have a high degree of reliability. Other data, such as origination or servicing, will have varying degrees of reliability. If the data is to support a critical model, then the types of controls over financial data should be considered for the other types of data.

Table 6.1 Type of data and their relative value

Factors affecting quality and quantity of data	Other indicative data	Servicing data	[illegible]	[illegible]
Input controls	None or very limited existence edits to ensure field is complete only	[illegible]	[illegible]	[illegible]
Quality assurance	Usually none	Little of the data subject to quality assurance monitoring	[illegible]	[illegible]
Independent review	Usually none	Usually none	[illegible]	[illegible]
Historical availability	Very limited electronic storage and unlikely to have been maintained through conversions	[illegible]	Some electronic storage but a low likelihood to have been maintained through conversions	[illegible]

DEGREE OF RELIABILITY			
LOW ←			[illegible]

COST/BENEFIT OF DATA COLLECTION

The reason for the disparity in how this data has been treated is because banks have not valued the information. However, this cost/benefit equation has undergone a significant change due to the CCAR process for several reasons. First, as previously mentioned, the regulators clearly expect banks to continually improve their data quality. This has been evident in their official guidance, in their feedback on monthly and quarterly submissions, and in their supervisory discussions with the banks. In fact, in July 2012[1] the Federal Reserve proposed that each bank's chief financial officer (CFO) attest to the accuracy of this data. However, in part due to industry feedback, the Federal Reserve recognised that the scope and form of the information collection have not been sufficiently solidified to allow the establishment of infrastructure, general controls and system validation requirements. While no attestation is required, the Federal Reserve has stated publicly that appropriate controls are crucial to ensure data quality, that attestation is an important affirmation of data quality and that they may revisit the attestation requirement in a future proposal. It is easy to understand the Federal Reserve's position, as this data is used to make critical decisions concerning the safety and soundness of the banking system.

There is precedent established by both the Federal Deposit Insurance Corporation (FDIC) Improvement Act and the Sarbanes–Oxley Act, both of which required certifications. Implementing those standards was expensive and time-consuming. However, these certifications both dealt with accounting controls over financial data, which had been subject to audits for a long time and had transparent materiality thresholds to guide management and regulators. Much of the new data is non-financial, and reconciliation controls are much more problematic to implement. Also, some of the data does not have a clear correct value. For example, many companies do not fit neatly into a particular industry code. An energy company may also own retail gas stations. Should it be categorised depending on which unit has the most revenue, fixed asset, profits or volatility?

These types of issues will make implementing controls to support an attestation over the other types of data listed above exponentially also more expensive and time-consuming. Additionally, as discussed below, the Federal Reserve intends to use this data in ongoing supervision. To this end, they have been encouraging the banks directly and indirectly to make significant investment into their internal control structures.

As part of the Federal Reserve's continuous supervision programmes for monitoring a bank's risks, they have a stated desire to use the data captured in the CCAR process for ongoing monitoring. In its role as the systemic risk supervisor, and given this new beginning of standardised data collection, there is meaningful analysis that can be performed within and across the large bank holding companies (BHCs). One could think of the data the FRB is collecting as similar to the data found in trustee reports filed for special purpose vehicles (SPVs). If you think of a bank as an SPV, the underlying BHCs can be thought of as sort of subsidiary set of SPVs that can be aggregated and analysed. Equipped with this data and analysis, it is easy to see how the FRB may be able, in time, to spot risk concentrations, observe cross-sector potential for cascading risk transmission across various product markets and better understand the riskiness of combined capital at risk at the system-wide level. Various elements of the data submissions are being used still by the supervisory community to spot trends across covered companies. This is fully consistent with the requirement under sections 165 and 166 of the Dodd–Frank Act (DFA) regarding enhanced prudential standards and early remediation requirements for covered companies. It is also not difficult to imagine a day when a model will be used to perform a loan review on the entire portfolio, not just a sample, or recompute a value at the risk amount, not just review calculations. A bank's risk management could be evaluated and scored with limited direct interaction.

However, the final reason to re-think the cost/benefit analysis may make that expense seem worthwhile: how the Federal Reserve treats missing data. Generally, in the design of a model incomplete or obviously erroneous data is dropped or adjusted in some way to ensure it does not adversely affect the model's accuracy. However, given that the goal of the CCAR process is to produce estimates of the capital necessary for a bank to weather a severely adverse economic situation and still remain well-capitalised and continue its intermediation role, the Federal Reserve takes a much more conservative stance. If a bank's submitted data quality is deemed to be too deficient to produce a robust supervisory model estimate for a particular portfolio, the Federal Reserve may assign a high loss rate (eg, 90th percentile) or a conservative PPNR rate (eg, 10th percentile) based on portfolio losses or PPNR estimated for other banks. If the data problem is considered to be isolated in a way that the existing supervisory framework can be still used, a conservative value will be assigned to the specific data. As bad as either of those two results might seem, if the Federal Reserve is sufficiently concerned about the data quality they can completely deny the bank's capital request, regardless of how much capital the bank is holding. This alone can justify significantly increased expenditures on people, processes and technology.

All of this data has focused on internal information – data generated by bank personnel during customer interactions. However, all banks are obtaining an increasing amount of data from external sources. This data varies from historical transaction data, time series of macroeconomic factors and even projections of future prices or conditions. As the data becomes more imbedded in the bank's processes, the sourcing and use of this information will need to be subject to some of the same controls and validations as internal data. Also, these services can be quite expensive and duplication of information is likely, as this data is often obtained by individual departments, that might be unaware of what else is available in the organisation.

Successful financial institutions will find ways to leverage this data-collection exercise to better inform their own internal risk identification, measurement and reporting processes. This includes adding certain elements to the underlying loan data collection, such as internal hierarchy field names, call report codes, unstructured data capture, images, forms and other required fields necessary to ultimately ensure reconciliation with the various internal systems and processes that are required to support the analysis, as well as tying back to external regulatory reports. More important may be the addition of additional financial and non-financial data elements that relate to an account, relationship, collateral or guarantor. The static data alone, those data collected through the FR Y-14M and FR Y-14Q, can provide powerful insights into a firm's exposure(s) and assist in various portfolio stratification reports that have remained elusive for many banks. Some firms have begun to consider how the data might be further enriched to support additional business needs of the bank, rather than merely responding to the regulatory mandate.

REPORTING STRUCTURE MISALIGNMENT

The above issues relate to the detailed individual loan or event data submissions, but there is another level of complexity added by most of the summary level templates that are required to be based upon FR Y-9 line items. The regulators had no choice but to use FR Y-9 categories in the original SCAP to have some level of comparability between organisations. Also, since that time, they have had to maintain the approach to have consistency from review to review. Unfortunately, banks are not organised along these categories, but rather by other criteria such as business line, product and geography. They do not actually model along these FR Y-9 categories, making it necessary to allocate modelled results to line items and impairing the ability to compare the results. A simple example is a commercial loan secured by a primary residence. The bank may have originally underwritten it, and continue to service it as a commercial loan, and is likely to model it with other commercial loans. However, since it is secured by a one-to-four family residence, it will be included in residential mortgages on the FR Y-9. As an interesting note, the proposed stress-testing framework for the UK does not require a mapping to a prespecified regulatory hierarchy such as the FR Y-9 but, rather, the Prudential Regulatory Authority (PRA) will work with their covered companies to map a bank's internal business reporting dimensions to the Firm Data Submission Framework (FDSF), which underpins the data collection efforts of the Bank of England (BoE).

For US banks subject to stress testing, and in order to meet the intent of integrating the capital planning process into daily risk management activities, the bank's systems must support aggregating and the reporting of stress-testing results along lines that are meaningful to the bank. However, the systems must also allow the same data to be reported along a completely different hierarchy so that the templates mandated by the Federal Reserve can be completed. The best systems will then allow easy translation of the information and results used by the bank to that supplied to the regulators. In addition to enhancing processes and systems to obtain, validate and audit all this data, there will also be a much greater need to persist the data through time. Increasingly, the regulatory expectation is that this data will be versioned so that new models can be run on old data to help understand the impact of changes, as well as old models being run on new data to benchmark and validate improved model performance. This will allow firms to show how incremental improvements have been made over time, as well as for various backtesting and improved internal model building.

DATA GOVERNANCE

The greatly increased need to obtain, store, manipulate, analyse and integrate data has implications beyond just the obvious needs for better processes, systems and controls. It will require a fundamental rethinking of how we view data. As customers and the world become more integrated, and given the fact that stress testing is not a US key regulatory initiative but an initiative by the G-20 and a Financial Stability Board (FSB) objective, banks are being required, by fiat, to become more integrated in how they make their money in managing risk. In most banks today, there are many different data owners, each in their own silo, very knowledgeable of their data and how they use it, but largely ignorant of how others in the organisation can or should be using it.

In order to wrap effective controls around a firm's data management processes, it has become increasingly common for large organisations, and even some smaller firms, to create a new C-level position: the chief data officer (CDO). The CDO is responsible for establishing data standards, policies, controls and accountability. Usually reporting to the chief technology officer (CTO), the CDO works to prioritise data acquisition, architecture, process controls and overall enterprise data strategy. However, the technology is not the difficult part of the problem. In many banks, data has never been treated as an asset of strategic corporate value. This has been a mistake. As tools to capture, mine and evaluate data continue to improve, the ability to better serve customers, create enhanced decision support tools, monitor trends, detect risks and form new opinions and insights regarding business opportunities has become much more profound.

As with many large corporate and information technology companies, banks are beginning to apply supply chain concepts to the flow of data, and are becoming aware that their data is a treasure trove of hidden information and, when combined with other data sources, can be exploited to enhance shareholder value. In fact, effective data management may emerge as a key competitive differentiator in the years to come, as the banking model itself comes under pressure and as firms with better control over data are also be able to improve efficiency, create better business intelligence and accelerate decision-making with enhanced information.

The implementation of a data governance framework can differ significantly from firm to firm; however, all data governance programmes involve aligning the organisation around improving the integrity of data capture, security, availability, storage and use. A centralised focus is needed to determine what information is required to meet the firm's goals, establish standards for business units to capture the information, source required information from external parties and make all of the data available for individual groups to exploit on an as-needed, just-in-time basis. For stress testing, governance activity has become focused primarily on establishing new policies and procedures for the remediation and filling-in of missing and low-quality data, and ensuring the completeness, audit, control and accountability for data enhancement across the organisation. However, for banks, as the amount of data increases and accessibility is expanded beyond a specific business unit, security and the need to know will become increasingly important to manage. This is true not only of the firms involved, and the data banks must maintain and improve, but for the regulatory agencies themselves. The level of data granularity required by the US supervisory agencies will require a pristine process for access control and user control. The next section of this chapter will provide insight into the comprehensiveness of the requirements in the US CCAR process.

STRESS-TEST REPORTING AND DATA COLLECTION TEMPLATES

In order to conduct a FRB-styled stress test, you must begin with the FR Y-14M/Q/A reports. The SCAP process created the recognition that few firms, if any, possessed the quantitative, rigorous process necessary to model a firm's entire balance sheet, income statement and *pro forma* regulatory capital. SCAP focused more on establishing public confidence that banks would have the capital they needed – by public markets or by government-mandated capital infusions. The CCAR process evolved to engender confidence that large, systemically important banks have the capital buffers needed to withstand stress.

To forecast risk to financial condition, including capital, requires an understanding of all the material exposures across the firm, the earnings produced by assets, the costs incurred by liabilities, and how these measures and management actions change under routine and adverse conditions. This includes unfunded commitments and off-balance-sheet exposures that, under stress, may revert to the firm's balance sheet, a significant risk that was not fully appreciated. The CCAR exercise is a dynamic forecast of all balance-sheet exposures with an eye toward credit, market, price and interest rate risks. While banks have measured interest rate risks through asset/liability management (ALM) models for quite some time (ie, since the last major financial crisis), the requirement to integrate credit loss estimates, non-performing assets, credit-adjusted new business plans, fair-value measures, including other than temporary impairment (OTTI) of investment holdings, dynamic non-interest income and expense, and provisions for loan and lease losses into the business process requires new approaches. To date, the solutions have been a patchwork of various existing risk and finance systems. In the future, banks will need to integrate across these systems and processes in a more efficient manner. It is important to note that, given the enhanced scrutiny of banks and risk profiles, and the critical role banks play in financial markets, as well as the advent of new credit intermediation mechanisms, the bank of the future may look fundamentally different. Executive management and the board of directors of banks need to ensure that the strategic direction of their firm aligns with emerging technologies and realities of changing business models.

To give a sense of the comprehensiveness of regulatory expectations around data, it would be useful to review the requirements of the Federal Reserve's stress-testing data collection efforts. The data templates required by the Federal Reserve for all banks over US$50 billion in total consolidated assets, subject to certain materiality thresholds, are complex and comprehensive. The reporting forms and submission templates include the following:[1]

- The annual FR Y-14A: The 14A is the annual output report that represents the summary CCAR *pro forma* analysis. This report collects forward-looking projections of a BHC's balance sheet, income statement, losses and capital across three different macroeconomic scenarios. This is the report that must tie back to mandated regulatory dimensions in the BHC's FR Y-9C filing. In fact, one of the first audit points of the supervisors is whether the FR Y-14A and FR Y-9C balances are properly reconciled and variances can be explained. The 14A is a risk and finance view and must be consistent with US GAAP, reconcile bank to other regulatory reports, follow rules of consolidation and consider the impact of emerging regulatory deadlines for various elements of the DFA and Basel III regulatory capital rules. For banks with trading portfolios, a separate report and market shock is required to be used, which substantially increases the complexity of scenario analysis and reporting.

- ☐ The quarterly FR Y-14Q: Collects a large amount of historical data on PPNR, historical regulatory capital and capital actions, summary data on various retail asset classes (including international), investment securities and granular data on commercial and industrial (C&I) and commercial real estate (CRE) loans. Much of this data is used to support the Federal Reserve's own model-building efforts, as well as to allow for off-site supervision and enhance the system's continuous supervisory monitoring bank examination programme(s).
- ☐ The monthly FR Y-14M: Collects granular data on loan level exposures, as well as various portfolio level measures, within the mortgage, home equity and credit card asset classes, including both portfolio and serviced loans.

In 2012, there were four changes to the various reports, and there continue to be changes and enhancements to the data requests requiring ongoing changes to internal data structures, models and related systems and business processes. Regulatory expectations are that these required changes – including data that may not have been collected before (eg, customer financial statement data) – will be implemented in an expeditious manner. While the Federal Reserve has not been overly critical of banks' efforts to date, it is clear that data completeness will become increasingly important. One drawback of this constant change has been that much of the initial response is based on *ad hoc* reporting, just as in the original SCAP request. However, as banks continue to work towards a sustainable, reliable and efficient process, the limitations of the existing data, technology and workflow becomes clear. However, at this stage of process maturity, the ability to fully integrate all of the required elements into one comprehensive solution is not attainable; too many separate business processes exist and the ability to integrate all of the required data, models, business plans, risk measures, accounting views, reconciliation methods and validation routines will require a firm-wide commitment toward an evolving enterprise architecture that will take years to complete.

In addition to performing stress tests utilising either the Federal Reserve's or the individual bank's macroeconomic scenarios, or stress-testing requirements from other jurisdictions, banks are coming under increasing pressure to identify and calculate idiosyncratic risk. Moreover, even various rating agencies are giving increased attention to a firm's ability to conduct stress tests in a comprehensive and complete fashion. The bank is expected to understand its business model, including securities, loans, deposits and revenue and expense drivers, to determine what unique events or conditions might impact its capital and, increasingly, its liquidity position. Banks are encouraged to run as many of these scenarios as possible, and consider what individual or combination of events could occur. Again, the bank is expected to aggregate this impact across the entire entity. Any *ad hoc* analysis is expected to demonstrate rigorous controls, including both the reconciliation and governance controls, to which the main scenarios are subject.

The intensity of the data quality management requirements, and the fact that errors in the process can potentially lead to unwanted regulatory remediation, is causing many banks to rethink data chains of custody, reconciliation processes and, perhaps most importantly, making data quality a critical element at the point of deal origination, data entry, and asset and liability boarding. In many cases, this requires inserting new technology within a firm's overall enterprise architecture that forces better data input, error detection and error correction at the point of deal capture.

DATABASE REQUIREMENTS

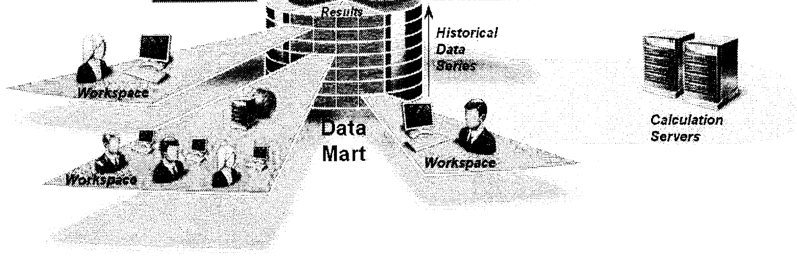
The data, rules sets, hierarchies and related information that underpin the stress test is ideally pulled from a common data store. In many organisations, this requires the acquisition or build of a specialised data mart,[3] or the augmentation of an existing data warehouse, to support the scenario design, CCAR/DFA stress tests

(DFAST) and capital planning process, and requires integration and interfaces across multiple pre-existing systems. This data mart must possess a data model that handles the required data inputs and result files that cover finance, treasury, credit, trading, mortgage banking, regulatory capital and – over time – liquidity (see Figure 6.1). The data mart must cover risk, finance, financial products, regulatory rules and reporting models in a comprehensive fashion.

Given the fact that the data and results will inform the bank's capital plan and possible regulatory approval of capital actions (such as dividends and compensation), the security, auditability, scalability, maintainability, versioning and efficiency of the data mart must be unquestionably strong. Whatever data mart and associated infrastructure is used, they will also need to possess the required structure to handle forecasts (ie, input and output data sets), multiple regulatory reports (eg, the FR Y-9C the FFIEC 031/041, the FFIEC 101 and (possibly) the FR Y-16) and instantiate required user, administrator, data custody workflows, as well as to persist extremely large volumes of data.

Even firms that have invested heavily in enterprise data warehouses have found that most data warehouses are not built for purpose for the regulatory mandated stress tests. This includes consideration of the numerous rules and edit checks necessary to link and reconcile across internal and regulatory reports, particularly where a bank is operating in numerous different countries or regions, each of which may have different scenarios, data, fore-

Figure 6.1 Data mart: contains scenarios, reference data and computational results for stress testing



casting horizons, aggregation, reporting, operational and other idiosyncratic requirements. This has meant that most processes rely on spreadsheets and many manual processes, which can be error prone.

In the development of solutions for the task, banks need to consider capturing data at the most atomistic level, as various areas of national discretion (such as in the UK or the stress-testing requirements of the European Central Bank, ECB) may require a variety of different aggregation points and forecast horizons. A firm that is able to capture position-level data can always aggregate-up to higher, pool-level cohorts; however, if a system is designed in reverse, starting with aggregation pools, the ability to move down towards the position level becomes more difficult and may run foul of various regulatory requirements by jurisdiction.

For US banks, it is not uncommon to find that numerous pieces of the Federal Reserve's data and risk measurement inputs are scattered across various sub-ledger and specialised risk, finance, loan accounting, servicing, collections, document preparation, origination systems and even custom spreadsheets and small databases, which have never needed to pass various of these data fields to a central data warehouse.

For example, when looking at the data request for the FR Y-14Q, corporate loan data schedule, there are 82 different data fields that are required. A similar level of data requirement exists for investment securities, retail loans, CRE and other exposures (eg, mortgage servicing rights, trading risk positions and PPNR). Numerous of these data fields are not simply for contractual information related to the loan, but the request asks for data that crosses the origination system, collections, servicing, loan spreading and loan accounting (ie, fair value and ASC 310–30). Table 6.2 provides an indication as to the expansiveness of the data request for C&I loans; similar requirements exist across all loan categories.

While these data can be placed in a central data warehouse, the need to link and reconcile to numerous regulatory reporting hierarchies, accommodate forecast input, absorb elements of the financial planning and analysis (FP&A) and ALM output, and store scenarios, scenario consistent market data,[4] business origination strategies, general ledger files and a range of assumptions across multiple business lines and geographies (while also allowing for automation of numerous workflows and workflows of workflows), requires

Table 6.2 FR Y-14Q – corporate loan data submission

░	Customer ID	░	Other credit facility purpose description	░	Guarantor internal ID	▓	Current assets current
░	Internal ID	░	Committed exposure global	░	Guarantor name	▓	Current assets prior year
░	Original internal ID	░	Utilised exposure global	░	Guarantor TIN	▓	Tangible assets
░	Obligor name	░	Line reported on FRY9C	▒	Guarantor internal risk rating	▓	Fixed assets
░	City	░	Line of business	░	Entity internal ID	▓	Total assets current
░	Country	█	Cumulative charge-offs	░	Entity name	▓	Total assets prior year
░	Zip code	█	FVA	▒	Entity interenal risk rating	▓	Accounts payable current
░	Industry code	█	ASC 310-10	▓	Date of financials	▓	Accounts payable prior year
▒	Obligor internal risk rating	█	# of days principle and interest past due	▓	Data of last audit	▓	Short-term debt
░	TIN	█	Non-accrual date	▓	Net sales current	▓	CMLTD
█	Stock exchange	░	Participation flag	▓	Net sales prior year	▓	Current liabilities current
█	Ticker symbol	░	Lien position	▓	EBITDA	▓	Current liabilities prior year
█	CUSIP	░	Security type	▓	Adjusted EBITDA	▓	LTD
▒	Internal credit facility ID	░	Interest rate variability	▓	Interest expense	▓	Minority interest
▒	Original internal credit facility ID	░	Interest rate	▓	Net income current	▓	Total liabilities
▒	Credit facility internal risk rating	░	Interest rate index	▓	Net income prior year	▓	Retained earnings
░	Origination date	░	Interest rate spread	▓	Cash and marketable securities	▓	Capital expenditures
░	Maturity date	░	Interest rate ceiling	▓	Accounts receivable current		
░	Credit facility type	░	Interest rate floor	▓	Accounts receivable prior year		
░	Other credit facility type description	░	Interest income tax status	▓	Inventory current		
░	Credit facility purpose	░	Guarantor flag	▓	Inventory prior year		

░	Origination System
█	Collections System
▒	Servicing System
▓	Loan Spreading System
▓	Other

considerable thought around architecture and design. In practice, this requires a fairly agile data layer. In some cases, necessary data, data layout or calculation output from one system, perhaps supplied by one vendor, may be contractually precluded from being used in another risk, finance or other third-party solution that is necessary for producing the stress-testing result(s). In some cases, this may be a potentially profound legal problem that has not yet been recognised or properly addressed by the supervisory authorities.

As banks begin to look at increasing their investment in improved infrastructure, these data stores and processes should not be created solely to support the stress-testing exercise. There is an expectation that the underlying structure of the internal design is coherent and that the internal plans are such that the data and processes are used to support multiple business purposes, including meeting what the supervisors consider the use test (ie, that the overall results, systems and processes are used in regular bank management and decision-making). This requires integration across existing and planned systems, and most firms are still in the design phase of this architecture. Firms are expected to develop a data infrastructure that allows them to support the stress testing on an ongoing basis, creating an automation and integration framework that allows for more frequent, timely and less error-prone submissions.

Based on most projects to date, it is likely that the boards and senior management teams will need to elevate the exposure and funding for the necessary data and technology initiatives. Much work remains oriented on compliance rather than meeting business requirements and needs. Clearly, the objective of the regulatory authorities is not merely to create a new cost centre. The expectation is that data, and the risk and forecasting processes they support, will enhance business intelligence and, as a result, produce a safer and less-fragile financial system. This will require significant work to explain the strategic utility of the new infrastructure pieces, showing how required elements of infrastructure will help improve overall business strategy, firm safety and soundness, organisational profitability, asset allocation choices and the ability to withstand stress. Banks will also need to consider how to supplement their internal data with other sources.

In many cases, data is simply missing or unavailable due to organisational changes, system sunsets, mergers and acquisitions, and other matters. The expectation of the regulatory authorities is that the internal systems will be enhanced over time, and that concrete strategies are in place to ensure that the bank is able to supply the required data to improve their estimates of losses and revenues over time. The following sub-sections cover some of the attributes and capabilities of the data foundation that banks will need to consider deploying.

Data persistence and versioning

Whatever data mart is used or built, it must permit the storage of all historical data: market data; scenario data (across jurisdictions and as needed for models for front-line business use);[4] instrument data; assumptions; model information and versions; input product; portfolio; accounting files; and related elements that support the creation of the required FR Y-14A report. The data mart should be designed to archive snapshots that contain all of the static data, transactions (including credit risk mitigants) and calculated data as of each specific reporting date. These snapshots must be accessible at any time with all available features, including processing (or reprocessing) and reporting. This feature facilitates data validation, data quality audits and regulatory review by allowing the user to go back to any given date and report and reproduce results that were run at that particular historical date, or run new versions of models on old data. This requires contemplation of model versioning within the database, such that the control layer (a separate element of a well-conceived data mart) can access prior model versions that were used across the historical period(s).

User workspaces

A workspace is an environment within the data mart that has its own partition for the particular user, business process, business unit or functional activity. This area would be the storage compartment for all required input and results files, as well as allowing for any required customisations, such as aggregations, supporting documentation or unstructured data. The detailed results of various processes that must cater to user needs – such as ALM, liquidity management, risk appetite limits/thresholds, capital plan tables (that may need to be populated), and budget and planning information – can therefore be stored and managed as required, with integration links built on top of the resulting data model design. The workspace concept also allows groups of users to configure and calculate risk and finance reports in many different ways. This might include running a credit risk loss estimation process using a bottom-up model, in one instance, and then executing a stored aggregation procedure to roll-up accounts and then use a portfolio challenger model. Such a capability, when integrated through a control layer and linked to the reporting engine, can permit sensitivity analysis around capital calculations that might result from model selection. While not necessarily material on a portfolio-by-portfolio basis, when champion and challenger models are used comprehensively, this sort of capability can assist in model risk management and in confirming the range of possible calculation and model risk error to internal audit, model validation staff and the bank's primary regulator.

Data integration

Data import should be done in an asynchronous fashion from multiple data stores using an import platform or other extract, transfer and load (ETL) tools. The data mart should be able to create, schedule, error detect and report around pre-built and required customised integration interfaces. The data system must be able to collect data from multiple sources and target a consistent format for end-users. This allows for one central location to load, enhance and review data quality as it pertains to stress testing and reporting.

Data model coverage

The data mart should have a data model that reflects the realities of both static data and related reporting, as well as forecast data and associated reporting. Dedicated tables and screens should be available to manage each type of data structure – such as market data, static data, transactions, parameters and any calculated data. Owners of data objects should be specified, easily managed and allow for error-filling by the business owners. The data mart must be consistent and quickly expanded around the required transaction-level reporting from the FR Y-14M and Q, and the data model(s) must accommodate and map to multiple charts-of-account, each of which may possess different aggregation rules (ie, budgeting and planning, ALM, FR Y-9C, FFIEC 101 and other reporting). This will require firms to rethink data sourcing and reconciliation routines for in-place legacy systems. Many firms have yet to cross this path due to costs, the steady state of existing functional processes (ie, if it isn't broken, why fix it?), resource and budget constraints.

Data quality, error detection and checking

Dedicated services and dashboards should be available for administrators and users to catalogue, visualise and report on errors and make corrections to the data. As noted, there must be logging of all changes made to data, with the change archived for audit purposes. Messages to business owners and data quality managers should be part of the platform, with such communication stored and available. The system should identify potential problem areas automatically and make use of prior data that has been stored to determine possible hot spots of data problems. The solution should allow for first assurance testing that nothing is missing relative to the firm's general ledger.

Where data is missing, the data mart should identify missing or potentially erroneous data. Some of this data may never be obtained; banks are unlikely to find it worthwhile to contact a customer with a 15-year-old loan to ask about origination data not captured. However, subject to user rules for the target data, systems should be smart enough to fill in the missing data and generate reports that summarise the data-filling assumptions. The data filling is usually carried out with a defined rule set that users must create. At times, these assumptions can be difficult to benchmark; however, the data mart should include the ability to chart data errors and data filling over time so that management can track improvement and begin to minimise the need for data fills and associated data assumptions.

Reconciliation

One of the most important pieces of the data challenge for CCAR, or any stress-testing regime, is reconciliation. Balances that are used throughout the process must be reconciled to multiple sources, including the general ledger and the holding company regulatory report filing (ie, the FR Y-9C), as well as roll-ups from the firm's business plan (ie, financial planning and analysis) and ALM hierarchies. The data platform should be capable of absorbing the required input files and allow the user to establish mapping rules to validate consistency across the multiple aggregation and roll-up points. This requires that the data model itself be populated with the required data tags that indicate the ultimate target accounts for the underlying data. This is difficult for data within subsidiary systems that are pre-aggregated. These balances must be identified during the implementation and documented. Problems can also occur when subsidiary systems, such as the general ledger or other input sources, change dimension structure, add or delete accounts, or when balancing accounts are used, such as suspense accounts, to account for temporary differences. Such complexity requires the ability to message and communicate around data challenges and questions from the data layer itself.

Document management and messaging

Given the requirements of the CCAR exercise, it is important that various documents be stored and versioned alongside the various data submission(s). The Federal Reserve requires detailed descriptions of models, assumptions and data. This is not simply a documentation exercise; it is an important component of ensuring and demonstrating that the appropriate governance is being applied to stress testing and capital planning. Publicly, the quantitative end-results – how much capital each bank has after the nine-quarter period, delta between beginning and ending capital, and how close the bank's estimates were to the Fed's estimates – get most of the attention. While there is no argument that these ending numbers are equally important internally, the assumptions and estimates behind the numbers are also critical. Why the macro-environment scenarios selected are the most appropriate for the bank, how these scenarios were used to estimate revenues, expenses and losses, and, most importantly, the limitations of each of the estimation techniques, must be understood by those making the final capital planning decisions.

Moreover, given the difficulty of reconciling across multiple underlying source systems, the need to message the various users and administrators of the overall CCAR data model will require ongoing communication within and across the various workspaces that make up the data mart and data assembly workflows. Owners of the various workspaces must be provided with playbooks that indicate how to manage account and hierarchy changes, and the data mart must allow for the identification and management of orphan inputs as well as data-loading errors. Each contributor to the data model must be required to follow a well-defined business process for adding and deleting accounts, or making changes to aggregation rules that might impact reconciliation processes. The data mart should allow for the loading of the firm's proprietary data dictionaries[6] to assist in mapping, reconciliation and control.

Task automation and scheduling

In most banks, books and records are given a hard close after one-to-three days after a month-end. While not all data from the FRB is required on a monthly basis, it is a sound practice to aim for the creation of internal processes that permit monthly data collection of all required data for the annual and quarterly submissions. While not feasible in most banks at this stage of system maturity, having monthly time series across the various input elements will set an internal KPI quality standard that can help motivate and encourage greater discipline around the required process constituents, as well as assist in enhanced operational processes, model development and model validation.

In order to assist in this automation, many data pulls, error detection, data filling, aggregation routines, automatic reporting and error messaging need to be scheduled via a task automation tool. Given the number of dependencies throughout the process, the sequencing of running the automated tasks is critical, and users that are unable to meet required timelines must develop procedures to handle delays, which may mean creating rules that use prior-period values for a current period if the delay creates a critical bottleneck in the overall stress-testing assembly process.

While the above are a few of the required elements of a data mart appropriate for the CCAR and capital planning process, the list is by no means complete. One of the most difficult parts of creating an automation platform for a bottom-up, enterprise-wide stress-testing programme as the Federal Reserve has specified is the orchestration of data workflows and associated business processes. It should be clear that the data mart must have a solid administrative (ie, data governance and oversight) component, as well as a data management workflow component. The system must allow on-the-fly design of workflows within established workspaces, as well as on-demand aggregations; however, and critically important, it must also permit the merging of workflows across various workspaces.

To this point, we have only discussed the overall minimum expectations and requirements of the data, and the potential need for customised data marts that support the enterprise stress-testing process. What is also needed is a control layer that can access the underlying data, initialise and properly parameterise the underlying models that need to use the data to develop loss, net interest income, non-interest income, non-interest expense and regulatory capital measures. This is not the primary function of the data mart. This orchestration tool must be able to pass scenario input, scenario-consistent market data and required model inputs, and receive output files from the firm's numerous credit models, PPNR tools, the firm's finance systems, the ALM system and place computed results into their proper result tables. There are few banks that have developed or invested in this control layer; however, the technology is established and available, even if not comprehensively implemented at this point in the evolution of stress testing and capital planning.

SYSTEM ARCHITECTURE

While stress testing has been in place for a considerable time, banks are only beginning to think through the design of systems and infrastructure that will allow them to enhance the automation of their stress-testing and capital planning processes. As noted, one of the biggest challenges of the stress-testing exercise is coordinating the various activities and requirements across the relevant stakeholders within a banking organisation, as well as ensuring internal and external reporting consistency across numerous management and regulatory reporting dimensions.

To design a technology environment that can streamline this data collection, it is helpful to link certain front-office, origination and supporting systems into a platform that allows for a more rigorous straight-through processing. This may not be entirely unintended by the regulatory authorities. Many banks have grown through mergers and acquisitions, and have not managed to keep their internal technology systems linked together in a manner sufficient to forecast *pro forma* financial outcomes. This environment created legal entity and business model structures which result in a level of complexity that, in periods of stress, create information bottlenecks and information dilution, increasing idiosyncratic and (when combined with other large banks) possible systemic fragilities.

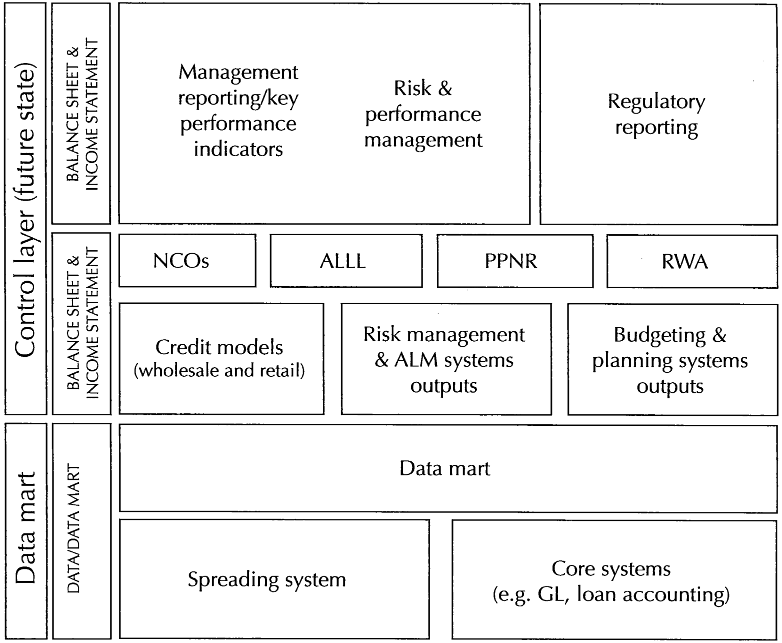
Platform overview

Figure 6.2 provides a stylised example of a possible technology platform that supports a modular, flexible and comprehensive approach toward the exercise. In the figure, there is a single data mart at the foundation of the architecture stack. As discussed above, this data model should contain all of the underlying scenario and market data, FR Y-14, FR Y-9C, FFIEC 101, risk, finance and treasury-dedicated data structures necessary to begin the analytic and reporting process. This data mart can be linked to the front-office risk origination systems to assist in populating various elements of the FR Y-14 data requests, as well as the numerous loan origination, servicing, loan accounting and collection systems (eg, including specialised areas, such as mortgage-servicing rights and the numerous regulatory specified stress tests associated with those assets). This data mart can act as the single source for all of the required data for the FR Y-14Q/M reports, and serves as the data source for all requisite scenarios and market data.

This data foundation may also be the central hub for all of the required data to initialise the bank's various models, and can be used to provide the required data feeds for the firm's ALM and budgeting and planning processes. Such a data store would generally require existing functional processes to re-engineer their data feeds and reconciliation processes; however, the efficiency gained by pulling from a common, dedicated source that is readily reconciled to internal and regulatory reports may be a worthwhile consideration for many firms. While potentially disruptive in the short term, this is an important consideration of system and data design as, ultimately, the goal is to service the needs of the business users, not simply create a process that satisfies the regulator. Clearly, both needs are important; however, the system design should be one that supports capital planning in a robust, ongoing fashion, as well as act as a solution for harmonising and integrating across multiple risk types. Ultimately, this data store will also need to be ready to support emerging liquidity risk requirements, which in the US are on the docket for implementation in the near term.

In the above platform design, the business process control layer is

Figure 6.2 Integration platform components


Control layer (future state)
BALANCE SHEET & INCOME STATEMENT
Management reporting/key performance indicators
Risk & performance management
Regulatory reporting
BALANCE SHEET & INCOME STATEMENT
NCOs
ALLL
PPNR
RWA
Credit models (wholesale and retail)
Risk management & ALM systems outputs
Budgeting & planning systems outputs
Data mart
DATA/DATA MART
Data mart
Spreading system
Core systems (e.g. GL, loan accounting)

>> The necessary solution design accommodates comprehensive regulatory reporting, internal risk and LOB reporting, plus dimension/hierarchy management:

- Executive and board-level reporting.
- Instantiation of the organisations risk appetite framework(s).
- Existing and expected liquidity risk reporting.
- Drill-through and scenario dependent PPNR, balance sheet, new business volume.
- Comprehensive wholesale and retail credit portfolio reporting.

>> The platform should be able to work within a firm's existing analytical layer to coordinate, enhance and improve risk transparency.

>> By linking results from point solutions to the reporting layer, a well designed platform can empower the bank by providing key linkage between input data and output results.

>> A well architected data-mart as an integrated risk and finance data layer, is the foundation for stress testing and reporting.

>> The data-mart should be fully integrated with various data sources, including enterprise data warehouses and core banking and loan accounting systems.

>> This platform layer is used for Dodd-Frank-mandated reporting (e.g. CCAR stress testing), DFA 165 and 166 requirements, Basel II and III, and emerging FBO rules.

not a form of middleware that all firms have contemplated; however, best practice is for firms to have a central control layer that can act as a sort of conductor to link various input data, assumptions, mapping rules, reconcilement routines, business processes and results from one central hub. This control layer allows for the integration of the firm's various credit loss and PPNR models, can provide consistent input data, as needed, to the bank's ALM system, can accommodate multiple approaches for handling conditional new business volumes with a granular forecast of Basel standardised and advance approach RWAs,[7] and non-interest income and expense items that are sourced from the firm's FP&A function (or can call additional models that might be used), and is able to orchestrate the workflow for the analytical inputs into both the regulatory and management reports.

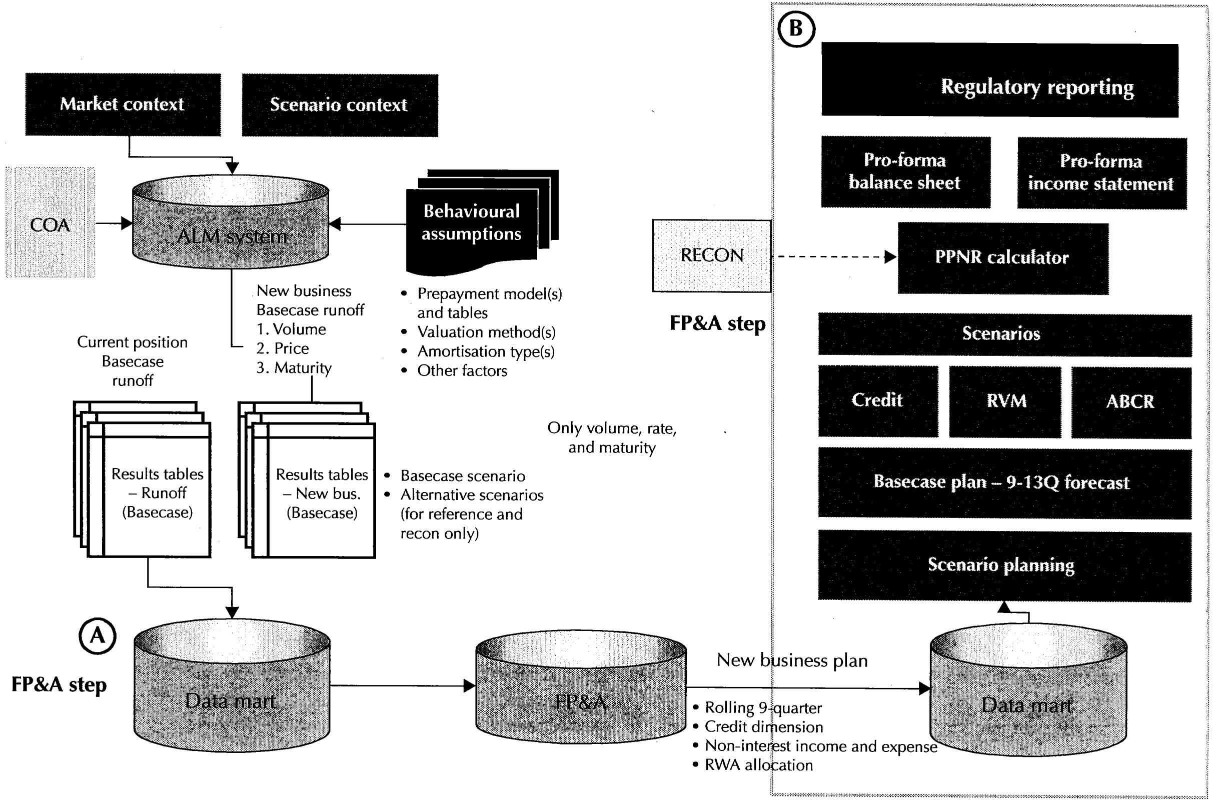
Stylised technical integration

As a practical example of how the complexity of a technical integration across the various groups might work, Figure 6.3 provides a reasonable perspective of cross-functional integration. For many globally significantly important banks (G-SIBs), this level of integration is not attainable at the consolidated level, as many of the underlying processes have been farmed out to geographic business units, forcing firms to rely on templates and spreadsheets of acquired/mandated data from each subsidiary business.

For less complex organisations, the target output, on the top right of Figure 6.3, is the regulatory report. For the Federal Reserve, this is the FR Y-14A report, which is a forecast of the firm's balance sheet, income statement and capital over a nine-quarter period. This forecast must be conditioned on specified macroeconomic conditions and comprehensively include conditional loss estimates (to feed the provision methodology), net interest income, non-interest income and expense, provisions for loan and lease losses and the allowance, and net income.

To create the proper workflows and data, the process might begin by seeding the organisation's cashflow tool with the necessary inputs. Due to the limitations of existing platforms, many organisations may insert various components, or more modern cashflow tools, into the process to assist in creating the required reporting. This may include scenario-consistent credit transition matrices to

Figure 6.3 Stylised architectural blueprint: integration of ALM forecasting and planning



ensure prepayments, non-accrual levels and loss estimates are properly aligned to the *pro forma* balance-sheet scenario and, in some instances, to compute Allowance for Loan and Lease Losses (ALLL) levels. It may also include appropriate new business volumes, indicative credit spreads for each scenario that have been quantitatively determined, as well as the relevant market data that is consistent with the economic scenario. The cashflow engine proceeds to calculate a base-case scenario that is then adjusted to fill the chart-of-accounts used by the firm's planning team (see Step A in Figure 6.3), which requires various allocation rules to be applied that might be different for the different scenarios. The financial planning and analysis team creates a new business plan on top of the base-case cashflows, and must also estimate base-case non-performing loans and assets, which may then be passed back to the ALM system to create a confirmed base-case scenario. At this point, however, the base-case scenario does not often include the proper credit or regulatory capital dimensions, and is void of any measures of non-interest income, expense or provisions that are consistent with the adverse economic scenarios.

Since most existing processes within banks do not accommodate the integration of credit, non-interest income and expense, firms are instead seeking to adjust the base-case estimate in a closed system environment that allows the organisation to have full control over the assumptions and changes necessary to augment the *pro forma* balance sheet, income statement and regulatory capital measures (see the vertical column in Figure 6.3). As mentioned earlier, most firms have relied on Excel worksheets and other manual processes, which is not a sustainable platform. Given the requirement for validation and transparency of the process, the entirety of the business process needs to be captured in a single environment. In Figure 6.3, this is the vertical column (Step B) on the right of the figure.

Once the base-case estimate is created, certain adjustments for credit-conditioned new business volumes, spreads and Basel risk weight category, non-interest income and expense, and provisions for loan and lease losses are made and linked to internal business processes. This includes the loss and recovery emergence processes, which are critical for the quarterly allowance for loan and lease loss calculations. As all of these adjustments are made in a closed system and managed by the above-referenced control layer, the traceability of the various assumptions and management overrides are easy to find and validate.

Business process workflow

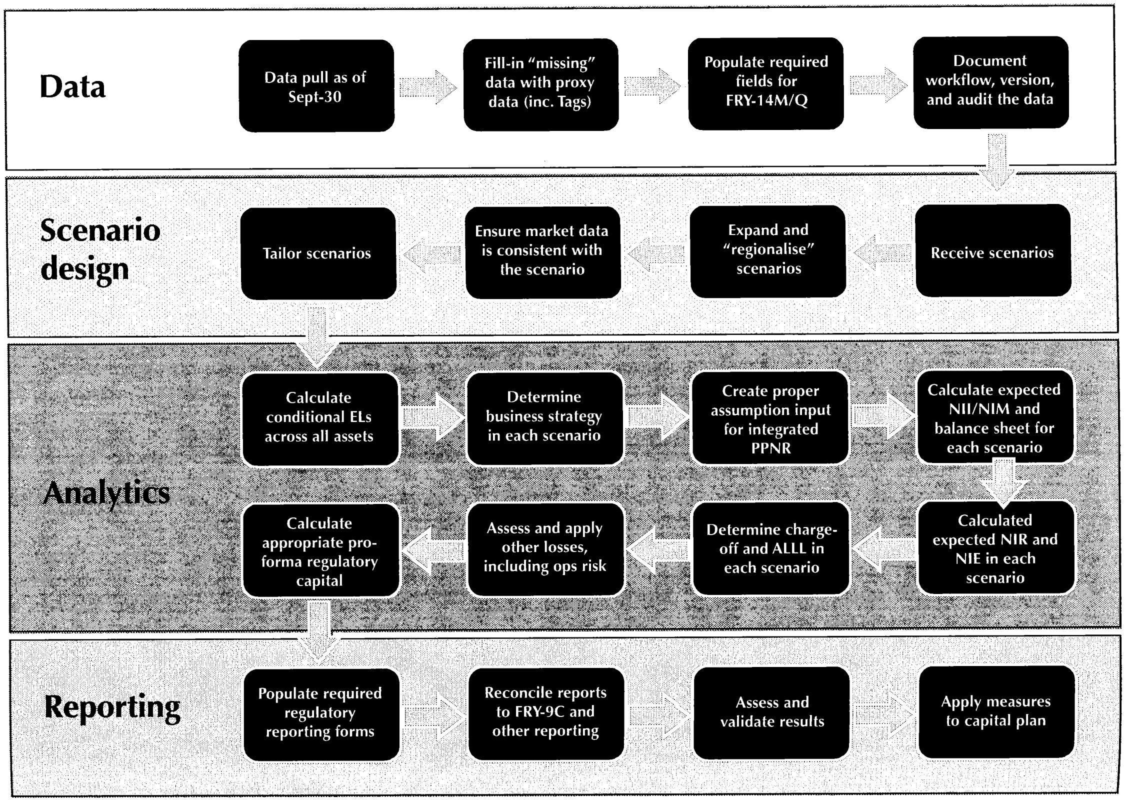
As should be clear from the above discussion, orchestration the workflow of the stress-testing process is difficult at the data-layer level, and also the analytical modelling and report assembly level. It is important to coordinate hand-offs between numerous groups within the organisation in a highly structured fashion, and timing is critical. This requires the use of scheduling software, workflow tools and management dashboards that allow the entirety of the business process to be mapped and managed as timelines and key dates approach. Workflows must be created not just for the data layer, but also for coordinating the hand-offs across the various lines of business and risk groups. The business process management (BPM) portion of the exercise is easy to minimise, but may be the most difficult part of the entire process.

To better understand the complexity of the stress-testing challenge, it is important to understand the linkages between disparate functions within an organisation. A high-level workflow of the entire process, which would be managed by both the workflow engine in the data mart and the control layer, is represented in Figure 6.4.

In Figure 6.4, everything begins with data. For the Federal Reserve exercise, the data-pull for the following year's submission begins with September 30 month-end data, and March 31 for the July 5 submission of the firm's mid-cycle stress tests. This means that all of the required data to populate the FR Y-14M/Q must be ready and prepared as close to the period-end as possible. The regulatory requirement is that this data submission is coincident with the same timing as the quarterly FR Y-9C (ie, holding company reporting); however, it is best practice to assume that this data is required contemporaneous with the firm's hard close of the monthly books and records. While ambitious, this is the goal set by many of the leading banks.

While much could be said about the above workflow, it is important to note here that within each element of this workflow (eg, imagine clicking on a box in the workflow) are different environments and workflows of workflows that must be designed and managed. While Figure 6.4 might naturally create the suspicion that

Figure 6.4 CCAR business process work-flow


Data
Data pull as of Sept-30
Fill-in "missing" data with proxy data (inc. Tags)
Populate required fields for FRY-14M/Q
Document workflow, version, and audit the data
Scenario design
Receive scenarios
Expand and "regionalise" scenarios
Ensure market data is consistent with the scenario
Tailor scenarios
Analytics
Calculate conditional ELs across all assets
Determine business strategy in each scenario
Create proper assumption input for integrated PPNR
Calculate expected NII/NIM and balance sheet for each scenario
Calculated expected NIR and NIE in each scenario
Determine charge-off and ALLL in each scenario
Assess and apply other losses, including ops risk
Calculate appropriate pro-forma regulatory capital
Reporting
Populate required regulatory reporting forms
Reconcile reports to FRY-9C and other reporting
Assess and validate results
Apply measures to capital plan

the workflow is sequential, this is indeed not the requirement or practical reality. Once the data is seeded, the workflow for the various elements can proceed. This is especially true if the control layer is in place and already pre-seeded with the required input assumption and scenario data needed for various downstream business processes to use. The ability to manage this workflow is critically important. In some organisations, the business process engine may colour code various elements of the process so that a percentage of completion is easily visualised. Each element of the workflow has a dedicated delivery schedule so that emerging bottlenecks are known well in advance, and additional resources or management horsepower can be brought to bear on trouble spots.

Last, each of the above work-steps may involve multiple functional groups within the organisation. Such dependencies and collaboration points should be well-defined and integrated into the process-mapping exercise. For example, the interaction between finance, credit risk, treasury and IT is a frequent intersection where multiple groups are dependent on one another to create the proper forecast. Establishing workspaces that allow for data assembly, modelling and report assembly is an important design consideration.

As an example, one of the most difficult business process challenges for the stress-testing exercise is how a firm plans forward-looking management actions under the various stress-test scenarios: the base-case scenario, and also the adverse and more-adverse scenarios. Business habits mean that the planning function does not plan credit risk, and the treasury (ie, ALM function) does not care to plan credit or RWAs. However, new business volumes need to be properly adjusted for the economic environment and scenario that is specified by either the bank (idiosyncratic scenario) or the regulatory authority, and credit and RWAs are critical elements of the capital planning process. These volumes need to consider the credit quality – originated, purchased or sold – of new volumes, subject to the scenario, and cover, at least, the full nine-quarter forecast horizon.

The management plan should be anchored by the existing riskiness of the current position (CP), and management should be able to easily plan how they would adjust CP credit quality in the various macroeconomic scenarios. The estimated new business volumes should be precise enough to allow for meaningful allocation to the Basel RWA categories on a *pro forma* basis, as required by the Federal

Reserve. The volume estimates should be informed not just by qualitative opinion, but by a quantitative estimate of the available demand in the given economic scenario (see the discussion of modelling below), and should be compared to the firm's risk appetite in the same scenario. The quantitatively estimated volume should be a function of existing market share versus the credit demand in the various scenarios. The model should also seek to estimate an appropriate credit spread relative to a specified reference curve for each credit quality rating bucket. Instantiating such a workflow is difficult and requires a solid control layer and BPM engine to ensure timely and meaningful results.

RE-TOOLING CUSTOMER INTERACTIONS

There is one key point that needs to be re-emphasised here. Most of what has been discussed has focused on how to make the stress-testing process more resilient and efficient. That is what is most pressing to both the industry and the regulators. However, in the longer term, customer interactions will need to be re-imagined. Some of this will be out of necessity – the need to capture more and different data than has historically been captured, and some out of opportunity – the more we know about the customer, the better we should be able to interact with them. This should ease the burden on the customer and speed the transaction. This is critical because, as anyone who has designed these interfaces knows, customers do not like to supply information, most particularly if they believe the bank should already possess it.

The centralised collection and storage of this information in standardised formats will aid this re-design. However, to achieve this, the ability of the business units closest to their customers to make autonomous decisions will need to be limited. It is important that banks strike the right balance of centralised control and business unit independence to continue to meet (and exceed) customer's expectations. Nevertheless, it is inevitable that this additional overhead will not negatively impact a bank's speed to market. Ultimately, the hope is that the improved execution of the strategy will more than offset any lack of nimbleness.

CONCLUSION

Stress testing is here to stay and will become increasingly important to all financial institutions. The techniques and approaches being developed by the Federal Reserve will eventually affect the supervision of all banks. Initially, the focus was on supporting the stress test with quantitative tools based on available data. However, the focus has shifted to making the process sustainable, repeatable and resilient. In addition, banks must seek out new sources of data, learn how to capture and control it, and make it available to the appropriate business units. To achieve this will require not only a substantial investment in technology, but also a dedicated effort to adapt new business processes. The technology cannot just automate existing practices that are not integrated.

While this chapter has focused on the data and technology implications of meeting the regulatory challenges, it has also suggested the most successful banks will be the ones who learn how to weaponise the insight gained from this work into better tools for their line staff. Data and technology exist to meet business purposes, and the business purpose of a bank is to take and appropriately manage risk. The financial crisis exposed many flaws in enterprise risk management capabilities, particularly around risk identification and measurement. A key goal of the stress-testing requirements being promulgated by various supervisory authorities provides both a challenge and an opportunity. The challenge is creating new processes and capabilities that develop a more integrated and comprehensive view of risk. This must begin with data. If anything was learned from the financial crisis, it is that the impact of rapidly changing circumstances, and the interaction effects across different risk types (eg, credit, liquidity and capital), require a much more agile and resilient data infrastructure at many firms. You cannot measure what you cannot manage, and one of the key goals of the stress-testing requirements is to focus banks on creating more adept processes to assemble, aggregate and act upon high-quality data, and the risk and financial forecasts that can be built upon such data.

Gleaning insight from improved financial and risk forecasting capabilities, and translating it into actionable steps for line bankers, will be difficult and require significant investments in new systems for data acquisition and management. New methods and techniques for BPM are being created to support heightened standards, and firms continue to work towards a future technology architecture that remains blurry. It will involve all business units and take a concerted effort, over a number of years, to implement. Banks will need to consider broader organisational implications, including re-alignments, new business process workflows, new key performance measures and new units, to achieve the full benefit of the required expenditure. Senior management and boards should be prepared to support this change with an appropriate structure and capital investment.

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1 See http://www.federalreserve.gov/reportforms/formsreview/FRY14A_FRY14M_FRY14Q_20120718_omb.pdf for more detailed information.

2 It is important to note that much of this data is not merely the submission of exposure information, but data that the Federal Reserve plans to use to build and validate its own internal models. These supervisory models are expected to improve over time, as their data repository across all banks grows, and will serve as a method for the agencies to challenge internal models as well as support the continuous offsite supervision of the subject banks.

3 A data mart is a specialised subset of a broader data warehouse. A data mart is usually oriented to get data out to business users, and align to a more specific set of business requirements, such as stress testing, regulatory reporting and/or capital and liquidity planning.

4 In numerous cases, various models require "market data" that may not be provided by the macroeconomic scenario. While the US provides various market data for trading book exposure in their global market shock scenarios, these market shocks are not appropriate for accrual book exposures. Thus, it is important for banks to "fill in" missing but consistent market data to ensure internal forecasts are consistent with scenario design.

5 Not all of the variables that are provided by the supervisory authority are relevant. For some models, there are significant gaps in the required data. For example, national unemployment, while highly correlated with unemployment in other regions, may not possess as high an explanatory power as unemployment by state, region, municipality or other more "localised" measure. In other cases, there may simply be more meaningful variables to explain default behaviour, business origination options and other required factors.

6 A data dictionary of a firm will reveal how the firm defines products, geographies, legal entities, ratings and other pertinent information.

7 In the US, due to the Collins Amendment to the DFA, many large banks will need to compute capital requirements under both the standardised and advanced approaches, and use the more conservative of the two measures in their capital planning.

7

A Multi-view Model Framework for Stress Testing C&I Portfolios

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Union Bank

This chapter will focus on a multi-view framework for stress testing commercial and industrial (C&I) portfolio. It will first discuss the challenges for stress testing wholesale portfolio, before introducing loss forecasting methods and a multi-view framework to properly assess and hedge model uncertainties. Besides probability of default (PD), the most important component of loss estimate in an expected loss (EL) framework, we will also explore several common methodologies to stress loss given default (LGD) and exposure at default (EAD). Finally, the chapter will conclude with a discussion of how to combine all these components to finalise recommended results from both a quantitative and qualitative perspective.

CHALLENGES FOR WHOLESALE STRESS TESTING

Estimating loss for the loan book under stress is problematic. On the one hand, the hypothetical scenario has not typically existed in history. Statistical models based on the historical relationship between loss and macroeconomic variables may not have fully reflected "accurate" sensitivity under the new regime. On the other hand, validation of models is also not straightforward. Unlike models used for baseline forecasting, where historical backtesting or statistical measurement usually provides a sufficient level of comfort of models' performance, validation of stress-testing models involves more. Two different model specifications can have very similar historical validation and yet produce significantly different out-of-sample forecasting under the same scenario.

Compared to modelling a retail portfolio, such as mortgage, credit card and car loans, estimating loss for a wholesale portfolio in general poses another layer of challenges, which will now be discussed.

Data size

The origination and performance data for retail portfolio usually consist of millions of monthly records. Default events are also commonly observed. Such sizable datasets pose considerable difficulties for loss forecasting with regard to data quality, integrity and complexity of data processing, model forms, key variable selection, etc.

In addition, wholesale data are much sparser and a portfolio can be quite "lumpy". Depending on the asset size of the bank, the number of accounts can range from a couple of hundred to tens of thousands. However, there tend to be quarterly financial-statement updates for public companies, and usually annual updates for private companies. For most regional banks, public firms are probably no more than 10–20% of the C&I book. Default events are also rarely observed; nevertheless, the impact can be significant due to the "lumpiness" of the portfolio. Establishing a causality relationship using such a small dataset poses a large challenge for many banks.

External data are usually leveraged to enrich the wholesale model-building dataset to underpin a robust and stable relationship. However, the representativeness of the external data to the individual bank's portfolio is a logical next step for an assessment of its suitability.

Optionality

The significant factor for stress-testing models is to be able to search for a valid and unbiased systematic, causal relationship between macroeconomic drivers and loss pattern. Whether the signal and relationship is strong or not mostly depends on the systematic risk that the individual borrower faces. To put it slightly differently, it depends on how much macroeconomic environment changes can impact the borrower. That said, if borrowers have more choice in responding to economic change, the impact is much more complicated to estimate.

In general, wholesale borrowers have much more choice than retail borrowers. Take mortgages, for example: the decision a borrower faces is whether to turn in the key or not. When a borrower experiences a pay cut or completely losing their job, making the mortgage payment no longer affordable (and, meanwhile, a slump in housing prices makes the liquidation of property unfeasible), the logical choice is to turn in the key and to rent, a much cheaper solution. As the primary driver for credit, housing prices are a key macroeconomic indicator, and the relationship is by its nature very strong. On the flipside, a wholesale borrower has more options available to them. To respond to the economic downturn, a company can cut its costs by shrinking staff numbers, reducing take home pay, slashing dividends, selling part of the business or asset to preserve its cash position, etc. In addition, it is common practice to hedge the asset value for some lines of business – for example, upstream oil and gas companies can take on an oil-and-gas swap or future to smooth out price volatility and stabilise cashflow. All of the above pose additional challenges for forecasting wholesale loss.

Credit signals

One of the main ways of managing a credit portfolio is to search for credit-event signals at a particular point in time. Statistical models that have been developed on a high-frequency observed credit signal have better performance and sensitivity to a change in loans/borrowers' characteristics. Again, take mortgages as an example: a borrower's FICO (Fair Isaac Company) scores are typically available quarterly, although some servicers can obtain monthly updates. Despite a full appraisal not being obtained unless borrowers are searching for refinance/selling opportunities, or the servicers order an appraisal because the borrowers have missed several payments, there are a few fairly granular housing-price indexes available in the market. Obtaining a proxy of the house price is not a concern. More importantly, the monthly delinquency pattern provides a strong and clear signal of the default tendency of borrowers.

Commercial borrowers, on the other hand, are less transparent. Financial statements are typically available only on a quarterly or annual basis. Quantitative financial ratios are only part of the indication of the financial health of companies. Qualitative indicators, such as the quality of the management team and the ability to manage through a downturn and vulnerability to any sector specific change, are not readily observable. The significant delay of information and complexity of obtaining a comprehensive assessment makes loss forecasting much more difficult, especially for private companies. The default pattern of commercial borrowers typically demonstrates a 0/1 type of last-minute event. Many non-accrual loans have not had any prior experience of delinquency patterns. Rapid downward migration can happen within a short time period due to the forward-looking adjustment/"fear factor" from credit experts. That said, the signal of default tendency is weak and credit deterioration could be sudden, posing another issue for commercial loss modelling.

Reliance on qualitative assessment and expert judgement

The assessment of credit risk for retail exposures relies heavily on quantitative models that, in general, produce PD, LGD and EAD estimates, leading to key risk measures such as expected loss, regulatory capital and economic capital.

For more sophisticated banks, loan-level models are usually developed to optimise the information usage for each account. For the less sophisticated, segmentation schemas are leveraged to group the portfolio into homogeneous pools. In either approach, expert judgement or overwrite are barely used. Retail products also have the advantage of being much more homogeneous assets with standardised product features and commonly understood key loss drivers.

The commercial side is almost the opposite, as commercial exposures are individually managed. Contracts are more customised for borrower's needs, and homogeneous pools are very hard to find. Take the C&I sector for example: the underline loans will be, at a minimum, differentiated by industry. Different industries may not react to the same set of macroeconomic drivers, and the timing of an impact does not necessarily occur at the same time. Also, quantitative assessment constitutes only part of the total assessment – some experts believe it is even less than 50% for many specific industries. Another element is the qualitative input to the scorecard, risk-level adjustment and overwriting after the preliminary scores from the scorecards. In stress testing, it is not feasible or practical to conduct these qualitative assessments and expert judgements for each exposure going forward for multiple quarters. Even if the credit experts are willing to perform such a task, the accuracy and reliability are in doubt due to a lack of experience and the historical benchmark of each individual company's performance in various hypothetical scenarios. A systematic proxy is therefore necessary in statistical models or quantitative modules in the scorecards.

Stress testing is generally difficult – however, forecasting commercial loss under stress is even more challenging. Compared to retail portfolio, data size is limited and default events are rare. Commercial borrowers have more ways of responding to economic downturn. Financial statements are available in a low-frequency fashion, which weaken the credit signal, increasing the difficulty of establishing robust and stable causality relationships. Credit professionals can then use expert qualitative assessment and expert judgement, such as qualitative input to the scorecards, risk-level adjustment and overwrites, to more effectively manage the portfolio. Nevertheless, this increases further the complexity of stress loss forecasting, which heavily (or even solely) relies on quantitative analysis.

In the next section, various loss forecasting methods will be presented and contrasted. In addition, an approach to handling some of these challenges discussed above will be explored.

LOSS FORECASTING METHODOLOGY AND MULTI-VIEW FRAMEWORK

Multiple methodologies are utilised to stress test commercial exposures, and several commonly used approaches are discussed in this chapter. The level of complexity ranges from developing a holistic view to forecasting loss directly, to loan migration models (internal, rating agency and expected default frequency (EDF) migrations) to forecasting each financial statement item, which then flow through scorecards to produce the PD. All models have their own assumptions and limitations; however, the authors believe that the use of multiple models to triangulate loss estimates in a multi-view framework is by far the best practice. Also, from the risk management perspective, there are strong incentives to link macroeconomic factors to the underline asset performance, ideally through financial statement impact, and then flow through the rating update route.

In this section, we will cover the top-down net charge-off (NCO) approach with three linkages from the industry to the banks' loss forecasts. It will introduce both the EDF and migration models, and the most sophisticated and powerful bottom-up approach will be presented. The use of a multi-view framework not only largely helps the model owner to put a triangulation around the final recommendation, but also to better understand, assess and hedge uncertainties around estimates. The use of challenger models to build greater comfort around primary model estimates has also been described as a leading practice by a study from the Federal Reserve Board.[1] In the study, the Fed also mentions that the use of the NCO model as a primary approach is lagging; however, we would argue that the use of a well-developed, parsimonious and transparent top-down NCO model as a tool for triangulation in a multi-view framework does serve as a valuable and advanced view in forecasting stress loss.

The top-down NCO view

The idea of top-down model is simple: the industry NCO rate is linked to macroeconomic variables using an econometric regression approach. In addition, the bank's own charge-off level is related to the forecasted industry NCO trajectory in three ways: by spread, multiplier and catch-up. This is a relatively straightforward approach, but it does provide a holistic and transparent view of the relationship between the bank and the industry risk profile. It assesses the portfolio-level risk assessment from the top.

One of the sources of industry NCO information dates to the 1990s, and it can be directly downloaded from Federal Reserve website.[2] Table 7.1 shows a sample of a NCO rate history for the 100 largest banks, covering both consumer and commercial loans, and lease portfolios.

Due to the quarterly NCOs observation frequency, there are only around 80 data points available to build a model. In order to avoid overfitting the historical data, the general rule of thumb is for at least 25–30 observations to support one variable in the equation. Therefore, this kind of top-down model typically has a maximum of two or three macroeconomic variables in the forecasting equation. Also, note that these types of time series tend to demonstrate strong autocorrelation.

Once the relationship for the industry NCO rates is established and the forecasts produced by feeding the model macroeconomic variables under different scenarios, the industry forecasts are then linked to the bank's internal NCO. Acknowledging the fact that the industry's loss experience does not perfectly represent the bank's

Table 7.1 Industry NCO rate history

	Real estate loans				Consumer loans						
		Booked in domestic offices									
	All	Residential	Commercial	Farmland	All	Credit cards	Other	Leases	C&I loans	Agricultural loans	Total loans and leases
2013:02:00	0.62	0.8	0.29	–0.25	2.28	3.53	0.9	0.17	0.31	0.01	0.84
2013:01:00	0.8	1.01	0.46	0.44	2.44	3.8	0.97	0.59	0.34	0.01	0.95
2012:04:00	0.93	1.14	0.4	0.54	2.58	4.04	0.98	-0.07	0.25	0.62	1.01
2012:03:00	1.52	1.98	0.54	0.64	2.55	3.85	1.11	0.34	0.39	0.58	1.32
2012:02:00	1.14	1.35	0.78	0.74	2.68	4.04	1.08	0.39	0.53	0.81	1.25
2012:01:00	1.3	1.55	0.97	0.47	2.84	4.35	1.1	0.24	0.53	0.53	1.32
2011:04:00	1.33	1.47	1	0.52	3.1	4.76	1.2	0.14	0.61	0.12	1.43
2011:03:00	1.52	1.68	1.22	0.61	3.68	5.7	1.36	0.16	0.64	0.27	1.66
2011:02:00	1.69	1.83	1.52	0.8	3.63	5.34	1.5	0.17	0.79	0.54	1.81
2011:01:00	1.78	1.88	1.85	1.16	4.71	6.97	1.89	0.29	1.14	1.15	2.15
2010:04:00	2.26	2.15	2.53	0.96	5.11	7.97	1.8	0.55	1.26	2.01	2.51
2010:03:00	2.3	2.14	2.72	0.84	5.54	8.62	1.98	0.44	1.71	1.97	2.81
2010:02:00	2.42	2.37	2.7	0.91	7.06	10.76	2.38	0.76	1.84	1.2	3.2
2010:01:00	2.65	2.75	2.74	0.85	7.08	10.55	2.63	0.94	2.04	2.92	3.36
2009:04:00	3.12	3.14	3.22	0.6	6.1	10.49	3.05	1.19	2.52	1.06	3.33
2009:03:00	2.67	2.74	2.65	0.64	6.11	10.36	3.37	1.33	2.64	0.95	3.18
2009:02:00	2.48	2.66	2.28	0.26	6.04	9.6	3.53	1.37	2.39	0.63	2.92
2009:01:00	1.81	2.06	1.66	0.23	5.14	7.64	3.28	0.81	1.89	0.5	2.29
2008:04:00	1.93	1.78	2.31	0.27	4.43	6.43	3	0.55	1.4	0.32	2.1
2008:03:00	1.39	1.68	1.14	0.07	3.64	5.39	2.57	0.49	0.98	0.27	1.62
2008:02:00	1.21	1.32	1.09	0.15	3.39	5.19	2.32	0.35	0.83	0.23	1.4
2008:01:00	0.8	0.96	0.69	0.16	3.1	4.6	2.11	0.4	0.71	0.05	1.09
2007:04:00	0.42	0.46	0.3	0.01	2.89	4.32	1.91	0.19	0.7	0.11	0.86
2007:03:00	0.25	0.29	0.11	0.12	2.64	4.07	1.71	0.26	0.47	0.12	0.71
2007:02:00	0.16	0.19	0.07	-0.01	2.43	3.71	1.61	0.19	0.41	0.04	0.6
2007:01:00	0.15	0.16	0.2	0.02	2.48	3.89	1.51	0.2	0.37	0.04	0.57
2006:04:00	0.13	0.13	0.11	0.14	2.31	3.72	1.26	0.14	0.24	0.32	0.48
2006:03:00	0.11	0.13	0.03	0.06	2.39	3.97	1.24	0.05	0.29	-0.01	0.53
2006:02:00	0.07	0.09	0	0.22	2.07	3.54	1.09	0.13	0.22	0.11	0.47
2006:01:00	0.08	0.09	0.07	0.06	1.83	3.1	0.97	0.26	0.2	0.19	0.42
2005:04:00	0.04	0.07	0	–0.08	3.33	6.11	1.18	0.65	0.21	–0.09	0.65
2005:03:00	0.08	0.08	0.05	0.11	3.29	4.43	2.39	1.05	0.15	0.01	0.72
2005:02:00	0.06	0.08	0.03	0.06	2.54	4.31	1.22	0.23	0.19	0.08	0.58
2005:01:00	0.07	0.08	0.06	0.15	2.66	4.49	1.25	0.38	0.23	0.07	0.61
2004:04:00	0.08	0.08	0.05	0.11	2.89	4.64	1.5	0.36	0.27	–0.13	0.59
2004:03:00	0.1	0.09	0.07	0.11	2.77	4.81	1.33	0.34	0.38	0.22	0.63

Table 7.1 Continued

	Real estate loans				Consumer loans						
		Booked in domestic offices									
	All	Residential	Commercial	Farmland	All	Credit cards	Other	Leases	C&I loans	Agricultural loans	Total loans and leases
2004:02:00	0.09	0.11	0.08	0.12	2.9	5.42	1.4	0.37	0.56	0.48	0.74
2004:01:00	0.13	0.14	0.08	0.06	2.86	5.23	1.41	0.5	0.79	0.45	0.8
2003:04:00	0.28	0.39	0.04	-0.04	3.01	5.6	1.3	0.54	1.01	0.55	0.89
2003:03:00	0.15	0.13	0.18	0.12	2.94	5.35	1.53	0.74	1.29	0.45	0.94
2003:02:00	0.17	0.17	0.14	0.18	3.06	5.58	1.68	1.01	1.47	0.24	1.04
2003:01:00	0.15	0.17	0.11	0.16	3.06	5.56	1.6	1.07	1.67	0.52	1.09
2002:04:00	0.16	0.15	0.15	0.29	3.02	5.17	1.55	1.56	1.74	0.98	1.07
2002:03:00	0.16	0.17	0.14	0.11	3.21	5.74	1.67	0.82	2.32	0.82	1.31
2002:02:00	0.18	0.19	0.13	0.18	3.19	5.84	1.6	1.01	1.98	0.96	1.29
2002:01:00	0.19	0.18	0.17	0.21	4.04	7.92	1.64	0.83	1.66	0.77	1.31
2001:04:00	0.23	0.22	0.2	0.37	3.2	5.49	1.64	0.76	2.26	0.25	1.28
2001:03:00	0.41	0.6	0.15	0.16	2.82	5.08	1.47	0.74	1.4	1.69	1.09
2001:02:00	0.17	0.18	0.12	0.38	2.6	4.8	1.28	0.52	1.24	0.95	0.94
2001:01:00	0.15	0.15	0.12	0.63	2.45	4.34	1.22	0.49	1.06	1.45	0.83
2000:04:00	0.12	0.16	0.04	0.32	3.16	4.36	2.12	0.32	1.18	0.85	0.92
2000:03:00	0.1	0.14	0.06	0.17	2.37	4.22	1.05	0.28	0.68	0.57	0.66
2000:02:00	0.1	0.1	0.07	−0.06	2.28	4.06	1.1	0.27	0.72	0.34	0.68
2000:01:00	0.11	0.14	0.03	−0.69	2.38	4.19	1.12	0.28	0.63	0.3	0.64
1999:04:00	0.11	0.16	0.02	0.06	2.48	4.34	1.19	0.34	0.64	0.21	0.68
1999:03:00	0.12	0.19	0.03	0.22	2.5	4.28	1.33	0.26	0.53	0.6	0.64
1999:02:00	0.08	0.12	0.03	0	2.33	4.34	1.08	0.31	0.55	0.55	0.64
1999:01:00	0.09	0.11	0.02	0.08	2.64	4.73	1.13	0.29	0.51	0.43	0.68
1998:04:00	0.04	0.06	0	−0.01	2.7	4.86	1.09	0.2	0.47	0.31	0.65
1998:03:00	0.05	0.09	−0.05	−0.08	2.7	4.94	1.11	0.26	0.37	0.11	0.75
1998:02:00	0.02	0.08	−0.08	0.27	2.87	4.86	1.22	0.26	0.32	0.02	0.67
1998:01:00	0.09	0.11	0.01	0.18	2.81	4.92	1.16	0.27	0.33	0.09	0.68
1997:04:00	0.04	0.08	−0.02	0.99	2.74	4.77	1.1	0.31	0.23	0.25	0.6
1997:03:00	0.08	0.1	−0.02	0.11	2.86	5.02	1.13	0.2	0.3	0.1	0.67
1997:02:00	0.05	0.11	−0.07	0	2.95	5.16	1.19	0.24	0.19	0.2	0.67
1997:01:00	0.07	0.11	−0.05	−0.06	2.69	4.6	1.13	0.23	0.17	0	0.6
1996:04:00	0.04	0.1	−0.04	−0.1	2.6	4.46	1.11	0.18	0.08	-0.06	0.54
1996:03:00	0.13	0.11	0.14	0.17	2.51	4.31	1.09	0.29	0.14	0.17	0.56
1996:02:00	0.12	0.12	0.11	0.15	2.45	4.51	0.98	0.19	0.23	0.13	*0.59*
1996:01:00	0.21	0.16	0.3	0.09	2.44	4.23	1	0.18	0.3	*0.05*	*0.65*
1995:04:00	0.17	0.16	0.26	0.06	2.26	3.92	*0.93*	*0.09*	*0.23*	*0.07*	*0.53*
1995:03:00	0.2	0.16	0.31	0.02	*2.15*	*3.77*	*0.87*	*0.03*	*0.32*	*-0.12*	*0.57*

1995:02:00	0.24	0.16	0.42	0.32	1.89	3.31	0.79	0.26	0.03	0.17	0.41
1995:01:00	0.25	0.16	0.43	0.1	1.74	3	0.7	0.04	0.22	-0.26	0.51
1994:04:00	0.46	0.22	0.93	0.24	1.91	3.5	0.67	0.05	0.13	1.01	0.49
1994:03:00	0.39	0.18	0.79	0.21	1.71	3.06	0.7	0.14	0.13	0.27	0.46
1994:02:00	0.57	0.25	1.19	0.17	1.79	3.2	0.76	0.09	0.22	0.17	0.69
1994:01:00	0.64	0.22	1.38	0.49	1.88	3.61	0.65	0.02	0.36	0.32	0.74
1993:04:00	0.85	0.25	1.69	0.67	1.99	3.73	0.73	0.31	0.5	0.28	0.95
1993:03:00	0.95	0.27	1.98	1.22	2.15	3.85	0.85	0.32	0.7	0.05	0.92
1993:02:00	1.18	0.33	2.47	0.59	2.23	4.18	0.9	0.43	0.87	0.18	1.05
1993:01:00	1.17	0.23	2.5	0.11	2.33	4.58	0.88	0.5	0.87	0.19	1.3
1992:04:00	1.88	0.34	3.72	0.45	2.58	4.77	1.14	0.78	1.06	0.27	1.49
1992:03:00	2.09	0.41	4.44	0.44	2.73	5.14	1.14	0.53	1.24	0.77	1.65
1992:02:00	1.5	0.21	2.78	0.19	2.95	5.5	1.22	0.69	1.25	-0.11	1.38
1992:01:00	1.54	0.2	3.02	0.52	3	5.29	1.36	0.68	1.81	0.3	1.85
1991:04:00	1.96	0.16	3.74	0.06	2.89	5.29	1.34	0.65	2.05	0.15	1.94
1991:03:00	1.62	0.19	3.14	2.94	2.93	5.28	1.31	0.8	2.08	0.99	2.17
1991:02:00	1.33	0.14	2.6	0.67	2.84	4.95	1.39	0.72	1.86	0.78	2.13
1991:01:00	1.14	0.16	2.14	0.55	2.65	4.48	1.56	0.81	1.18	0.68	1.69
1990:04:00	1.5	na	na	na	2.41	3.83	1.55	0.53	1.2	0.12	1.67
1990:03:00	1.04	na	na	na	2.21	3.79	1.1	0.74	1.09	–0.16	1.31
1990:02:00	0.9	na	na	na	2.12	3.22	1.41	0.56	1.41	–0.47	2.16
1990:01:00	0.88	na	na	na	2	3.23	1.26	0.77	1.34	–0.68	2.07
1989:04:00	0.78	na	na	na	1.98	3.26	1.08	0.55	1.7	–0.19	2.35
1989:03:00	0.66	na	na	na	1.89	3.13	0.98	0.41	0.72	–0.21	1.17
1989:02:00	0.5	na	na	na	1.86	3.27	0.93	0.44	0.71	0.43	1.2
1989:01:00	0.45	na	na	na	1.95	3.26	1.15	0.43	0.83	0.52	1.09
1988:04:00	0.42	na	na	na	1.89	3.52	0.84	0.35	0.69	–1.19	1.11
1988:03:00	0.51	na	na	na	1.88	3.41	0.91	0.38	0.85	0	1.21
1988:02:00	0.75	na	na	na	1.76	3.54	0.85	0.53	1.15	0.01	1.19
1988:01:00	0.46	na	na	na	1.71	3.42	0.8	0.38	1.06	0.85	1.24
1987:04:00	0.65	na	na	na	1.89	3.5	0.92	0.67	0.87	2.23	1.12
1987:03:00	0.47	na	na	na	1.73	3.27	0.84	0.63	0.86	-1.82	0.84
1987:02:00	0.42	na	na	na	1.84	3.56	0.85	0.73	0.93	1.49	0.77
1987:01:00	0.48	na	na	na	1.83	3.65	0.82	1.04	0.96	7.3	0.92
1986:04:00	0.46	na	na	na	1.8	3.37	0.81	0.63	1.16	0.33	0.85
1986:03:00	0.47	na	na	na	1.92	3.67	0.87	0.65	1.15	3.63	1.01
1986:02:00	0.39	na	na	na	1.89	3.48	0.97	0.58	1.19	5.44	0.97
1986:01:00	0.27	na	na	na	1.88	3.49	0.94	0.6	1.1	3.31	0.91
1985:04:00	0.22	na	na	na	1.72	3.12	0.89	0.77	1.1	4.5	0.84
1985:03:00	0.22	na	na	na	1.55	2.89	0.79	0.83	1.15	3.75	0.85
1985:02:00	0.24	na	na	na	1.4	2.53	0.71	0.67	0.87	2.88	0.74
1985:01:00	0.25	na	na	na	1.1	2.06	0.56	0.35	0.98	3.19	0.71

Source: Federal Reserve website

loss experience due to different portfolio concentration, underwriting standards, etc, the mapping is calibrated in three ways. As a result, the models provide three views of the stress loss. The linkage is not meant to be prescriptive, but rather a transparent way for the senior executives, subject matter experts and model users to gain a clear view of the bank's relationship to the industry. These three approaches also provide senior management with the flexibility to factor into the forward-looking view a purely historical perspective. For example, a bank going through a major expansion/acquisition may want to adopt a catch-up approach even if historically it has always outperformed the industry average.

If a bank wants to compare itself with its peers rather than the industry aggregated data, it can receive charge-off rate data for individual banks and bank holding companies (BHCs) from Federal Deposit Insurance Corporation (FDIC) call report data. Such a dataset allows one to potentially construct a charge-off rate series for the various asset classes of peer banks.

Multiplier approach

The underlying assumption of the multiplier approach is that the sensitivity, defined as the ratio of NCO rates between periods, is consistent between industry portfolios and the bank's portfolios. An average multiplier for each year of forecast was calculated by comparing the modelled NCO in each quarter to the modelled NCO in the last in-sample quarter. Expressed mathematically, the multiplier for each year is calculated as:

$$m_i = \frac{\sum_j^{j+3} \left(\frac{NCO_j^{IND}}{NCO_0^{IND}} \right)}{4}$$

where j is the beginning quarter of the year i.

The multipliers are then applied to the NCO of the bank's portfolio in the last observation point to yield a multi-year forecast:

$$NCO_i^{bank} = NCO_0^{bank} \times m_i$$

Spread approach

The underlying assumption of the spread approach is that there always exists a constant spread between the industry portfolios and the bank's portfolios. The spread is calibrated as the difference between the modelled industry NCO rate and the bank's NCO rate in the last in-sample data point.

$$s = NCO_0^{IND} - NCO_0^{bank}$$

This spread will be applied to each quarter's forecast of industry NCO rate to yield a multi-year forecast.

$$NCO_i^{bank} = NCO_i^{IND} - s$$

Catch-up approach

The underlying assumption of the catch-up approach is that, under stress, the bank's portfolio behaves no better or worse than the industry portfolio – ie, the two NCO time series converge, starting from the first quarter of the forecast and then overlapping. For banks that consistently have NCO rates lower than the industry, it is a punitive estimate, although the Comprehensive Capital Analysis and Review (CCAR) banks may not recognise the full benefit of historical outperforming from the regulator's perspective.

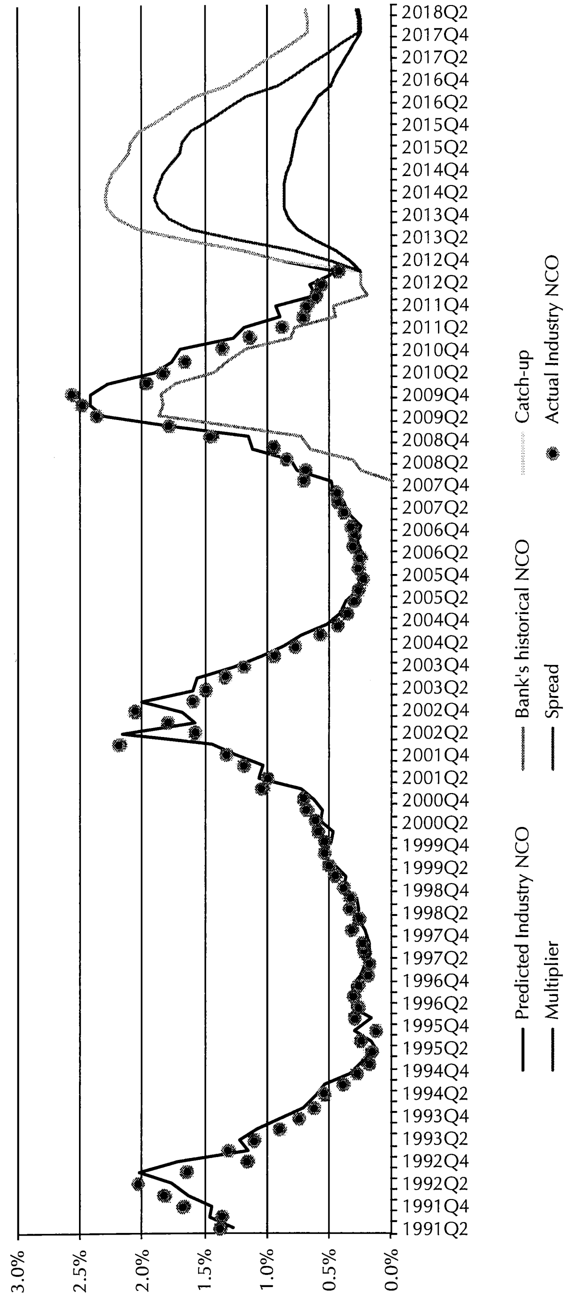
The forecast of the industry NCO rate will be used to yield a multi-year forecast:

$$NCO_i^{bank} = NCO_i^{IND}$$

Figure 7.1 presents a hypothetical example of the top-down model and the three linkages. The bank's historical NCO rate behaves in a similar way to a constant spread, although not exactly to that of the industry NCO during the last downturn period. In this case, a spread linkage is more appropriate as the point estimate. The catch-up and spread may serve as the upper or lower bounds.

In addition, note that as an alternative, instead of using the industry data, one can receive charge-off rate data for individual bank and BHCs from FDIC call reports. Such a dataset allows one to potentially construct a charge-off rate series for the various asset classes of peer banks. The resulting series could be more suitable than using the aggregated series if the peer banks' portfolios are deemed more representative than one's own portfolios.

Figure 7.1 Example of the top-down model



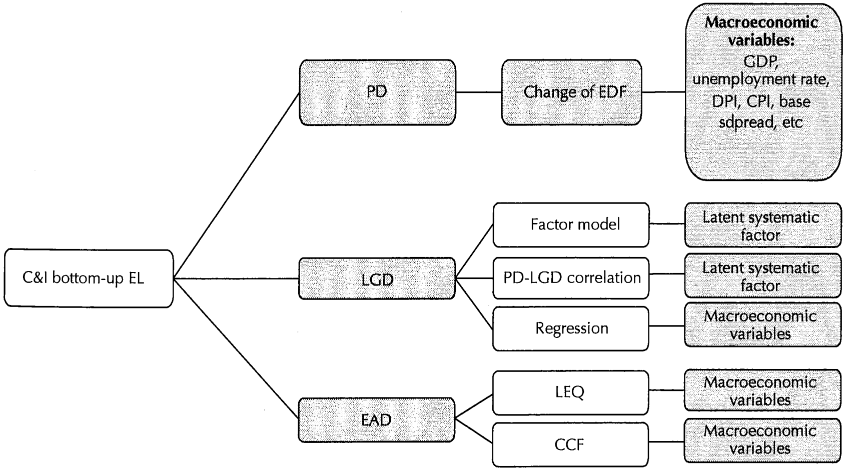
EDF view

The other view, the EDF approach, lies between bottom-up financial statement forecasting and top-down NCO forecasting, and relates the median change of EDF in the industry and credit bucket level to a change in macroeconomic indicators. The change of the EDF is applied to the current obligor PD level and rolled forward to forecast the PD level under various scenarios.

According to the CCAR document,[3] the Federal Reserve uses a very similar approach to model bank losses. Due to the marked-to-market nature of EDF, when the equity market is volatile, EDF will move up and down accordingly. Therefore, this approach is believed to be more punitive and volatile in general, especially when applied to the banking book, which is not marked to market. However, it does provide a market view of the portfolio and is also useful for the valuation of Held-for-Sale (HFS) securities.

Looking at some numbers for context, the historical maximum nine-quarter cumulative industry NCO rate for C&I is 4.4%, which includes the previous 2008–09 downturn. The Federal Reserve estimated a median cumulative nine-quarter loss under the 2013 CCAR severely adverse scenario for the 18 BHCs as being 6.5%. Taking into account portfolio improvement and the tightening of underwriting standards, the scenario difference should contribute minimally to the

Figure 7.2 C&I EDF model driver map example



delta. Also, from the perspective of the size of their loan books, the 18 largest BHCs are representative of the industry. We would argue that the 50% difference is mainly due to the EDF approach, which is in general more punitive when applied to loan books, as well as the difference between accounting NCO and economic EL (discussed in more detail later in the chapter).

Migration view

The rating migration model links macroeconomic variables to the rating dynamics to estimate the upgrade/downgrade probabilities. It indirectly assesses the PD or NCO through the change of the obligor's risk profile in different economic cycles. Obligor-level and bucket-level models are commonly used.[4] The loan-level model leverages obligor-level information, such as industry, size and past migration path, in a multinomial regression to estimate the migration tendency. The bucket-level model, on the other hand, leverages annual or quarterly migration matrixes to establish regression equations in a bucket-by-bucket fashion, or in a single distribution shifting fashion affecting all migration buckets from an initial rating similar to the RiskMetrics single-factor approach.

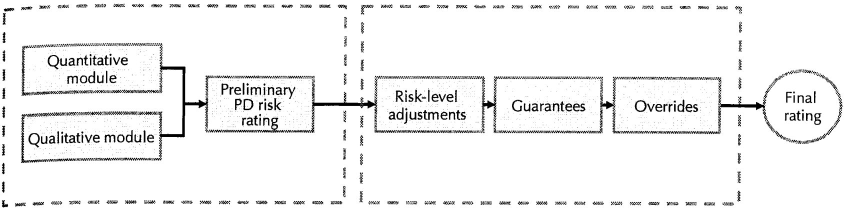
The migration model can be used as one of the methods to forecast stress loss and, more importantly, in Allowance for Loan and Lease Losses (ALLL) and risk-weighted assets (RWA) forecasting, where exposure distribution forecasts across risk buckets are essential.

Bottom-up view

Being opposite to the top-down, EDF and migration approaches, bottom-up models are much more complicated and yet are the most granular view for capturing exposure-level characteristics. Bottom-up models, which link macroeconomic variables to the key company performance metrics such as balance-sheet and income statement items, then applies these variables to the banks' internally developed scorecards, yielding a stress PD estimate. Most of the bank's scorecards have both quantitative and qualitative modules. The quantitative modules leverage both balance-sheet items (eg, total asset, end-cash equivalent) and income statement items (eg, net sales, net profit margin) to derive a preliminary score. A typical banks' C&I PD scorecard would be in the form shown in Figure 7.3.

From a risk management perspective, this type of bottom-up

Figure 7.3 Example of banks' C&I PD scorecard



Scorecard

- The statistical model estimated the PD based on a small number of quantitative and qualitative factors
- The factors are chosen during the modelling process based on their predictive power on a development sample
- The PD, which is calibrated to an agreed-upon estimate of the long-run default rate is then mapped to a PD rating

Manual adjustments

- After the statistical model has rated the obligor, there are a number of potential adjustments:
  - risk-level adjustments take into account factors that cannot be incorporated into the model (eg, bankruptcy of a major customer);
  - guarantees account for the presence of a guarantor/ parent company; and
  - final override – allows the final rating to be adjusted.
- These adjustments will be codified to take into account current policy to the extent allowed by Basel II regulations

approach is what risk managers are most familiar with. When they receive a borrower's updated financial statement, they will spread the financials according to the bank's policy and re-run the scorecards with both the quantitative inputs and qualitative assessment to obtain a preliminary PD assignment. They will also look for industry trends, the borrower's position within certain industries and other borrower-specific characteristics (such as legal, management, business or financial warnings) that are not factored into the rating process. Based on those inputs, they will apply risk-level adjustment and override accordingly.

Therefore, the appeal of this type of bottom-up approach is to have a direct linkage between stress testing and the day-to-day risk management practice. It is crucial to have a means of forecasting the borrower's financial statements under stress scenarios and let the normal risk management process run its own course.

Two approaches can be taken to forecast the borrower's financial statement.

- ☐ Link each scorecard input to the macroeconomic variables. That said, for all financial ratios both balance-sheet and income statement items are individually forecast. The drawback is that some of the balance-sheet items may not have a strong relationship with macroeconomic conditions. For example, the end-cash equivalent may not be cyclical as companies may liquidate some of the assets or business to preserve cash. However, the cyclicality will need to be reinforced to serve the purpose of stress testing. The performance of the model will be weak.

- ☐ Link the key financial items, especially the ones from the income statement, to macroeconomic variables. Net sales (revenue), cost of goods sold (CGS), selling, general and administrative (SGA) expenses, interest expenses, etc, are the key items used to reconstruct the income statement. The forecasted income statement leads to the forecasting of balance-sheet items with several assumptions. For example, with positive net income, the conservative assumption will be to keep the balance sheet constant assuming the net income is distributed as dividend.

To overcome the limited number of the collected financial statements across time faced by most mid-sized banks, external data can be leveraged. Two external data consortiums that provide sizable obligor-level financial-statement history are CompuStat for public companies and Moody's CRD for private companies.

The model will be applied at the obligor level, although the relationship can be extracted from the industry's median growth to avoid capturing the excess and pronounced idiosyncratic volatility for commercial borrowers.

To take into account qualitative assessment and expert judgement, such as Risk Level Adjustments (RLA) and overwrites, which are the key components of commercial rating system, two proximities can be leveraged. First, the typical "guide rail" bounds of financial ratios in the scorecard are relaxed to simulate the systematic downgrades and overwrites. The rationale behind this is that the credit experts will typically pay closer attention to, and review, those obligors with financial ratios outside the normal range. Under stress, the out-of-bound ratios should be examined and differentiated in the quantitative assessment.

For example, most C&I scorecards have leverage ratios such as total debt/cashing operating income as an input factor. In the scorecard set-up, there will be an upper bound when the leverage goes beyond a certain threshold, the statistical model will not produce further higher risk scores and expert judgement is utilised to override the final grade if necessary. During the normal course of business, very few firms will breach the threshold but, under stress, due to the deterioration of cash operating income, the threshold is much more likely to be breached. Therefore, by moving out of the threshold in stress testing, those firms that breach this threshold will automatically be assigned a higher PD due to the relaxing of the bounds.

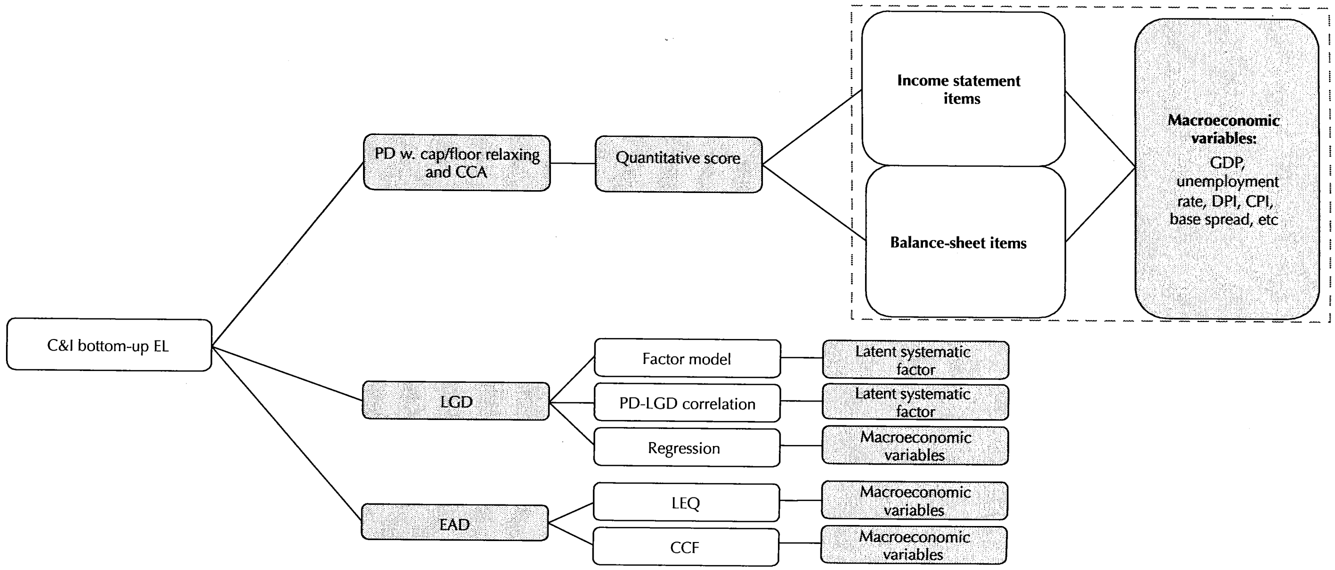
Second, the sensitivity of PD estimates to the economic cycles should be increased to compensate for the delayed information from the financial statement. Credit Cycle Adjustment (CCA), similar to the Moody's RiskCalc, is one of the best approaches. The ratio of CCA EDF and financial statement only (FSO) EDF can be modelled using macroeconomic variables. The FSO-liked PD from the scorecard can be adjusted with the forecasted ratio to behave more cyclically. Figure 7.4 presents an example of a flow chart of the bottom-up approach.

All the top-down, EDF, migration and bottom-up approaches described above are popular and commonly used for loss forecasting, ALLL, RWA, etc, to various levels of sophistication. Acknowledging the fact that models are the simplifications of the real world and all models are subject to assumptions and limitations, it is necessary and important to assess their uncertainties. Moreover, such an assessment is only half the job, the other being the best way to "hedge" those uncertainties. In other words, how can model users, who apply the loss estimate as the input to their various key performance metric forecasts, or the regulators, who examine the bank's capital adequacy, be comfortable with the loss estimates? In stress testing, this issue is mostly the underestimation of risk.

Some may believe that uncertainty can be identified and managed by calculating a confidence interval, say 95%, and using that as the range estimate. We argue that the best approach is to develop a multi-view framework, where the final loss estimates are the results of a triangulation from various approaches in the framework. All these models are developed based on their own assumptions and techniques, but they are all pointing in the same direction – ie, producing loss forecasts under different macroeconomic scenarios. Moreover, the performance of each model is assessed through backtesting, both in-sample and hold-out sample, as well as historical benchmarking, which compares the level of stress under a severe hypothetical scenario and the Great Recession.

The convergence of outputs largely reduces the uncertainties of

Figure 7.4 C&I bottom-up model driver map example



the estimates and provides a much higher level of comfort for loss estimates. The difference produces a range forecast, which is the assessment of uncertainties. In terms of the bigger picture, the uncertainties of each model are "hedged" in the multi-view system, making it superior to the statistical confidence interval approach.

In addition, vendor models such as Commercial Mortgage Metrics (CMM)/Property and Portfolio Research (PPR) Compass for commercial real estate (CRE), RiskCal for C&I and risk frontier for economic capital can be used as external benchmarks. However, conclusions must be carefully drawn. The difference in underlying data – commercial mortgage-backed securities (CMBS) versus internal in the CMM/PPR example and, in underlying model structures, random simulation of the state of economy versus deterministic paths of economic indicators in the risk frontier example – requires thorough analysis and comparison in the interpretation of results.

LGD AND EAD

The chapter has so far focused more on the PD side; however, LGD and EAD are also key risk parameters in forecasting loss. Although it is a challenge to estimate commercial PD under stress, it is even more difficult to forecast LGD and EAD.

LGD is largely driven by the recovery from the liquidation of underlying collateral. For unsecured exposures, the LGD becomes difficult to forecast. Even for exposures that are secured, the valuation for some collateral, such as blanket lien and accounts receivable, is not easy (if not impossible). We will now present several approaches for LGD and EAD.

Factor model approach

The underlying assumption of the factor model approach is that the factor for LGD is a linear combination of a systematic and an idiosyncratic component. The link function between the factor and LGD value is assumed to follow some distribution – for example, inverse logit transformation. Given a realisation of the latent systematic factor, the conditional LGD is derived:

$$LGD_i \Big| x = \frac{\overline{LGD_i}}{\overline{LGD_i} + e^{\beta_i \cdot x} \times \left(1 - \overline{LGD_i}\right)}$$

where $\overline{LGD_i}$ is the unconditional LGD (unstressed LGD) and x is the latent systematic factor.

PD–LGD correlation approach

The underlying assumption of the PD–LGD correlation approach is that the PD–LGD correlation is realised through the individual correlation to a systematic latent factor. The conditional LGD is then a function of unconditional LGD, systematic LGD volatility, latent factor and the LGD correlation with the systematic factor:

$$LGD\big|x = E\left[\overline{LGD} + X \cdot \sigma_{sys} \cdot \rho_{LGD-X} \middle| X = x_{1-\alpha}\right]$$

Regression approach

The underlying assumption of the regression approach is that LGD has a relationship with macroeconomic variables. The forecast of macroeconomic variables leads to conditional LGD estimate:

$$LGD = f\left(macroeconomic\ variables\right) + \varepsilon$$

Each or all approaches can be used at the individual exposure level or to scale up the mid-point LGD in the banks' internal LGD scorecards.

In general, EAD is modelled using a loan equivalent (LEQ) factor or credit conversion factor (CCF). Whether these two factors are cyclical depends on the banks' risk management practice. It then becomes a race to see whether the banks can freeze the line fast enough before the additional draw from distressed obligors. Detailed data and regression analysis is necessary to determine whether the relationship between EAD and macroeconomic variables is significant. If EAD is deemed not cyclical, additional stress buffers may be applied, such as downturn EAD from Basel.

PUTTING IT ALL TOGETHER

When an organisation adopts a multi-view framework, one of the questions commonly asked is how is it possible to make a final recommendation when there are multiple results? To help answer this, here are some key points to consider:

- ☐ pros and cons for each approach;
- ☐ difference between EL and NCO;
- ☐ model forecasting capability under different scenarios;

Table 7.2 Pros and cons for different stress-testing models

Models	Pros	Cons
Top-down	• Leverages industry loss data • Easy to implement and understand • Transparent • Provides median loss rates to compare • Has three interpretations/ linkages	• High level • Uses simplified assumptions • Expert judgement needed for bank's relevancy • Bank's obligor-level characteristics not directly used
Bottom-up	• Direct link to the bank's loan portfolio • Leverages internal risk-rating tools • Detail at obligor-level characteristics • Separate risk parameter estimates: PD, LGD and EAD	• Difficult to develop • Requires large amount of historical data, internal and external • Not as transparent as the top-down models
EDF	• Provides mark-to-market view of the portfolio loss • Leverages internal PD score as the starting point • Separates risk parameter estimates: PD, LGD and EAD • The Federal Reserve is using a similar approach	• More punitive for the banking book • Bank's obligor-level characteristics not directly used
Migration	• Gain insight of rating migration dynamics • Leverages internal rating migration pattern • Essential for ALLL and RWA forecasting	• Difficult to model accurately for all buckets • Requires long history of migration matrices

❑ balancing the credit loss and the ALLL balance-building process; and

❑ balancing the model results and expert judgement overlay.

We will now examine each of these issues in turn.

Understanding the pros and cons of each approach

Table 7.2 summarises the pros and cons of four different approaches

Understanding the difference between EL and NCO

The major differences between EL and NCO are:

- EL is economic loss, while NCOs are an accounting loss concept;
- EL assumes all the loss contents will be immediately realised, while NCOs need to factor in the liquidation/resolution process, and also timing; and
- NCOs have a timing mismatch between the gross charge-off (GCO) piece and the recovery piece that are not from the same pool of loans.

Due to the above, during a downturn period EL tends to be larger than NCOs. Therefore, the question becomes whether there is any way to assess the magnitude of the difference. When calculating economic loss, LGD models take into consideration discounted recovery cashflow and work-out cost. On the other hand, from an accounting loss perspective, there is no direct discounting of cashflow and the work-out cost is an expense item in pre-provision net revenue (PPNR) forecasting. Take C&I portfolio as an example: assuming a typical economic LGD for C&I loans to be around 40% and work-out costs to be around 2.5%, this means the net recovery after discount is 62.5%. If we assume the typical loans resolution process is around one year and the discount cashflow rate is 10%, before discounting the recovery would be around 69% (= 62.5% * 1.1). In other words, if one only focuses on the accounting losses without discounted cashflow and work-out costs, the accounting LGD will be 31% rather than 40%. Therefore, the EL could be around 30% higher than the NCO.

Model forecasting capability under different scenarios

As part of model risk governance, model backtesting and out-of-sample forecasting capability are very important. It is also crucial for the model to be able to offer a reasonable forecast under different scenarios.

We have seen many models that have similar performance regarding the historical data but perform very differently during the forecasting horizon. However, there are rules that can be adopted for forecasting capability around model transparency, conforming to risk management process and historical loss compatibility, etc.

Balancing the credit loss and the ALLL building process

From the total credit impact perspective, it is not only about the pure credit loss, but also PPNR forecasting impact and the ALLL balance-build process in the final provision estimates. Although this chapter does not cover PPNR items, it does describe here the ALLL balance-building process.

This is also where the banks' general practice diverges from the regulatory treatment in CCAR stress testing. Regulators leverage an EL approach to determine ALLL balance at each quarter-end. According to the Federal Reserve's disclosure document, the forward four-quarter ELs are totalled as the ALLL balance at any given point in time. This makes perfect economic sense. However, most banks' ALLL processes will not be able to adopt this economic view for C&I portfolio due to accounting requirements. Most banks' ALLL have significant balance built during downturn, which typically links to sub-portfolio loss rates tied to look-back periods. In stress testing, the ALLL balance will increase dramatically due to the double-hitting impacts of both loss rates going up and the portfolio rating migrating downward. The ALLL for a typical commercial bank's C&I portfolio could be up to 60% of the credit loss.

Examining all the components of stress forecasting, if a banks' models are to generate the same magnitude of credit loss as the regulator's models, the provision impact would be 1.6 times that of the regulator's models, including the 60% of ALLL.

Balancing the model results and expert judgement overlay

Compared with retail models, wholesale models are especially necessary to balance the model results and expert judgement overlay, which is apparent in the day-to-day management of the wholesale credits.

Modellers all strive to build the best models for predicting stress losses, but unavoidably encounter situations where certain regime changes are not reflected in the historical dataset. One example could be, if new regulation was passed, to assess the impact of healthcare reform on borrowers in the healthcare industry. Modellers can develop models to assess the impact, but it is also fundamentally important to factor in expert judgement on top to make it a more robust process. As part of the stress-testing governance structure, any expert judgement overlay applied should be clearly documented with evidence of support.

In an ideal world, stress loss estimation should involve a full suite of automated models that can easily produce loss results for any given scenario. It is important to achieve both consistency and efficiency, and especially to have a fundamental understanding of the magnitude and timing of the losses. A multi-view framework provides the capability to "look at" the same scenario from different angles and understand the similarity and differences of various results.

CONCLUSION

Stress testing is difficult; modelling commercial loss is even more challenging. Limited data size, greater optionality for obligors responding to economic downturn, weak credit signals and qualitative assessment and expert judgement all pose extra layers of complexity. These challenges enlarge the uncertainties of statistical models – therefore, a multi-view framework comprised of multiple models is deemed best practice to triangulate the final point estimate, as well as provide range estimates. Top-down NCOs, bottom-up financial statement forecasting, and EDF change and migration models are all commonly used and popular candidates in the framework. LGD and EAD are equally important in loss forecasting. Although they are to some extent more difficult to model than PD, rigorous analysis is necessary and several approaches can be leveraged.

The authors have already applied this framework for internal capital adequacy assessment processes (ICAAP) and CCAR exercises. The level of transparency and comparison between industry and bank that this framework provided were well received. Senior executives have a much better understanding of the portfolio and are much more comfortable with providing sign-offs. Although the amount of work is significant, it is well rewarded for improving risk analytics and framework, leading to a better overall risk culture.

1 Federal Reserve Board, 2013, "Capital Planning at Large Bank Holding Companies: Supervisory Expectations and Range of Current Practices", August 20.

2 http://www.federalreserve.gov/releases/chargeoff/chgtop100sa.htm.

3 Federal Reserve Board, 2013, "The Dodd–Frank Act Stress Test 2013: Supervisory Stress Test Methodology and Results", March.

4 See CreditMetrics Group, 2007, "CreditMetrics Technical Document"; Moody's Analytics, 2013, "Stress Testing of Credit Migration: A Macroeconomic Approach", May 13.

8

Stress Testing Credit Losses for Commercial Real Estate Loan Portfolios

Jun Chen

Moody's Analytics

This chapter will discuss the estimation of credit losses for commercial real estate (CRE) loans under the stressful macroeconomic scenarios formulated by the regulators in conducting stress-testing programmes. The focus is to provide a coherent analytical framework where the top-down macro view can be married with bottom-up, loan-level specifics to derive accurate credit loss estimates for CRE loans.

CRE loans constitute a large share of the loan portfolios for most commercial banks. Approximately one-fifth of the loan book in the commercial banking universe is CRE loans. The investment risk and return characteristics of CRE loans differ from commercial and industrial (C&I) loans, and the unique features of this asset class warrant specialised analytics to address stress-testing needs. Due to the high-risk nature in CRE lending, particularly construction loans, regulators have long been wary of the risks of possessing too much CRE in a single bank's loan book. Even before real estate helped trigger the 2007–08 financial crisis, in December 2006 the Office of the Comptroller of the Currency (OCC), the Board of Governors of the Federal Reserve System and the Federal Deposit Insurance Corporation (FDIC) jointly issued inter-agency guidance to address financial institutions' increased concentrations of CRE loans. Entitled "Concentrations in Commercial Real Estate Lending, Sound Risk Management Practices", they stated that "... an institution with CRE concentrations should perform portfolio-level stress tests or sensitivity analysis to quantify the impact of changing economic conditions on asset quality, earnings, and capital. Further, an institution should consider the sensitivity of portfolio segments with common risk characteristics to potential market conditions."[1]

In the aftermath of the financial crisis, under the new financial regulatory regime the importance of stress-testing direction has re-emerged in the credit risk management arena. Guided by the Dodd–Frank Act, regulators are demanding stressed credit loss estimates given explicit macroeconomic assumptions. For example, the US Federal Reserve System has published guidelines, as well as baseline and stressed macroeconomic assumptions, for the Comprehensive Capital Analysis and Review (CCAR) programme each November since 2011. The Federal Reserve's guidelines lay out very specific, hypothetical macroeconomic scenarios regarding GDP growth rates, unemployment rates, inflation, interest rates, etc, and require major bank holding companies (BHCs) to provide, among other things, credit loss estimates as specified in the baseline and more adverse scenarios. However, the Fed does not provide detailed technical guidance on how losses should be estimated – rather, the burden is for banks to "... substantiate that their results are consistent with the specified macroeconomic environment, and that the components of their results are internally consistent within each scenario," and also to "... describe the underlying models and methods used in their loss estimate calculations for loans, and provide background on their derivation."[2]

Unsurprisingly, financial institutions are in full alignment with the regulators, as both strive for the safety and soundness of banks' balance sheets, and scenario-based stress testing has been proven over time to be a valuable tool to aid clarity during the risk management process. Because credit risks are asymmetrically distributed, with heavy loss potential during stressed periods, it is of particular value for financial institutions to measure how credit losses might accumulate during stressed economic conditions as dictated in the CCAR programme.

In our view, macroeconomic scenario-based stress-testing best practices consist of:

- ☐ macroeconomic scenario design balancing downside severity with plausibility of the event occurring;

- ☐ appropriate analytical methods taking into consideration the unique risk characteristics of asset classes analysed;
- ☐ translation from macroeconomic scenarios to direct risk drivers of different asset classes – a structural or quasi-structural modelling approach is highly desirable to ensure consistency and logical dependency;
- ☐ taking into account the idiosyncratic characteristics of individual institutions' portfolios;
- ☐ a robust technology infrastructure that captures data accurately and performs sophisticated analysis in a timely manner; and
- ☐ a thorough understanding from business users in terms of explicit/implicit assumptions, as well as confidence interval or uncertainty around the expected results.

While it may look intimidating at first, building a robust analytical framework for CRE loans is feasible once we fully understand this asset class, gather sufficient historical data and design appropriate methods to address CRE's unique risk profiles.

We will discuss the unique characteristics of CRE loans in the next section, before comparing commercial banks' CRE loans to that from other types of lenders. We will propose a coherent CCAR stress-testing framework for estimating credit losses, followed by details on translating macroeconomic scenarios into key measures of CRE markets, as well as a methodology to quantify the default and loss rates under stressed scenarios. We will also touch upon the subject of model validation and appropriate context, and ways to interpret scenario-based model results; the penultimate section will discuss expected loss, unexpected loss and mitigating overlay, before we present some conclusions.

CRE LOAN CHARACTERISTICS

In order to appropriately stress test the downside risks of CRE loans, we first must have a thorough understanding of the inner workings and unique risk profiles of the CRE asset class. Commercial properties are income producing, capital-intensive, yet irreversible, investments. Commercial properties are classified typically by loan purpose and property type at a macro level. Table 8.1 shows how regulatory classifications[3] of CRE loans fit into the conventional classifications used by industry practitioners.

Table 8.1 Classification of CRE loans

Conventional industry category	Regulatory category
Permanent loans	Multi-family Non-farm, non-residential – other Non-farm, non-residential – owner occupied
Construction loans	One-to-four family residential construction Other construction, land development, land, additions or alterations to existing structures

Of the above, owner-occupied, non-farm, non-residential CRE loans rely typically upon the borrowing entities to make timely loan payments instead of relying upon the rental income generated by the underlying commercial properties. As such, the creditworthiness of these borrowers primarily influences the probability of default, and hence an analytical framework from C&I loans appears to be the most appropriate for them.[4] All the others from the above list should be analysed within the CRE framework.

Most commercial properties are not easily convertible to alternative uses – for example, it is very difficult and expensive to convert a shopping centre into a useful space for office workers. To capture the specific market conditions and cycles based upon the intended purposes of the commercial properties, practitioners typically group commercial properties by their specific property types:

❑ multi-family;
❑ office;
❑ retail;
❑ industrial;
❑ hotel; and
❑ other, such as self-storage, parking garages and healthcare.

Multi-family, office, retail and industrial are commonly referred to as "core" property types, as these four not only have the largest overall share, but also reflect the most fundamental investment characteristics of the CRE asset class: income predominantly generated from rents paid by the tenants occupying the properties. Any other property types are viewed as "non-core," in that they either have a much smaller share (eg, self-storage, parking garages), or they operate like a business in addition to being a commercial property (eg, a hotel needs to be both a good real estate and good business operator in order to remain profitable). Practitioners sometimes find more granular definitions useful – for instance, among retail property types, regional shopping centres may operate quite differently than smaller neighbourhood centres; among hotel property types, full-service hotels can also differ significantly from limited-service hotels.

An important feature of the CRE asset market is its low liquidity, low transparency and high transaction costs. The price discovery process can be very long for CRE, as both leases and sales do not begin and close until after many months have passed. The commercial property leasing market operates in the competitive market for space, and the property ownership market operates in the competitive market for capital. Between the markets for space and capital, since space is a necessary input into a firm's day-to-day production process (companies need office space, retailers need store space, manufacturers need industrial and warehouse space, etc), the market for space is much broader and more observable than the thinner market for property ownership.

As construction cycles are long, the existing stock remains roughly the same, making CRE market cycles react to the macroeconomic movements with lags. While many commercial properties operate like businesses – ie, running an apartment complex or a large shopping centre is not that different from running a company with income (generated from rents) and expenses (employees to take care of the property and customers/tenants) – one key difference is that the growth/upside potential of a particular commercial property is fundamentally limited by its location and physical size. To some extent, it actually helps to limit the complexity of analysis.

Borrowers use CRE loans to finance their investment, and the loans are collateralised by the underlying commercial properties – ie, the main source of periodic loan repayments come from the operating income generated primarily by rents from commercial properties net operating/capital expenses. The repayment of the balloon principal (most CRE loans are structured to have one) comes from either refinancing or sales proceeds; this is the case for both permanent loans (including mini-perm) and construction loans. For construction loans, because the projects under development typically do not generate rental income, interest owed is usually capitalised into the loan balance, and the total unpaid loan amount is repaid after the developers sell the new construction or refinance the construction loan balance into a permanent loan.

CRE loan investment risk focuses primarily on credit risk for the majority of the commercial banks holding the CRE loans until maturity. Most commercial mortgages have a 25–30 year amortisation schedule, while the term of maturity is substantially shorter (5–10 years) and a large balloon payment typically remains at loan maturity. As such, the credit risk should be viewed as composed of both term risk and maturity risk.

COMMERCIAL BANKS' CRE LOANS COMPARED TO THAT FROM OTHER TYPES OF LENDERS

Commercial banks have the most diverse lending practices and are the most viable lending source for the CRE industry. The loan products offered by commercial banks include short-term construction loans, mini-perm and longer-term permanent loans. The breadth of the products and mix of lending practice is unrivalled by either insurance companies or commercial mortgage-backed securities (CMBS). In our estimation, more than half of US commercial banks (around 7,000 FDIC-insured banks) actively participate in some sort of CRE lending. Some focus on construction loans (especially small, regional banks that have a natural advantage in local lending markets), while some focus more on longer-term permanent loans on stabilised properties, and each bank selects a lending business strategy suitable for the banks' funding source, duration of liability, expertise, mix of asset allocation, risk appetite, etc.

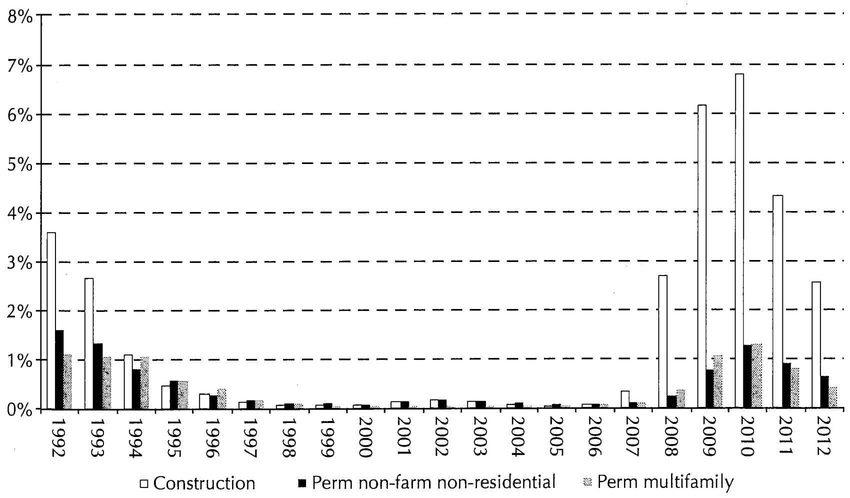
Note that some foreign banks or US subsidiaries of foreign banks also actively participate in the CRE lending space. A noticeable specialty of commercial bank CRE lending practice occurs with construction loans, which neither insurance companies nor CMBS originate. Even specialty lending shops rarely finance commercial property construction projects. Such diverse lending practices across commercial banks makes credit risk model development and validation a significant challenge, and banks may benefit from a combination of analytical methods. For example, a top-down analysis can be helpful in examining the macro-level reasonableness of estimated loss levels and a bottom-up, loan-level analysis can provide more much granular differentiation across loans. Meanwhile, and more importantly, a bottom-up analysis captures today's portfolio composition as opposed to historical portfolio compositions.

Figure 8.1 shows annual gross charge-off rates broken down by loan purposes for all the commercial banks in the call reports.[5]

We see that the construction loan segment is historically much more volatile when compared to either multi-family or non-farm, non-residential permanent loans, and the latter two segments are actually quite similar in their historical credit performance. While the concept of expected losses (EL) differs from the concept of charge-offs, which can take longer to realise, it appears clear that the cumulative losses for permanent loans over the last cycle (2008–12) is about 4%,[6] while the cumulative losses for construction loans were substantially higher.

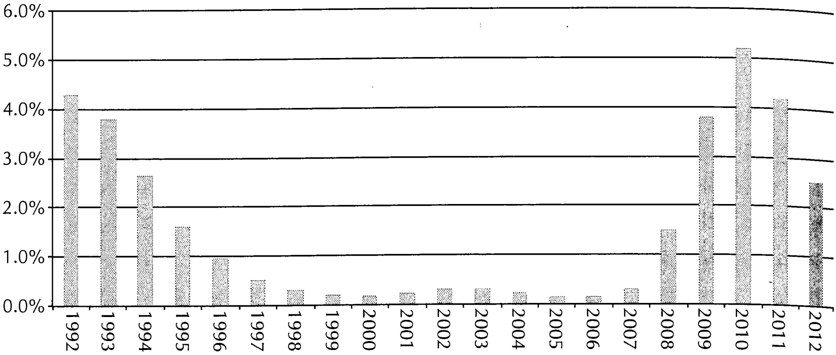
We next look at cumulative nine-quarter charge-offs (see Figure 8.2). The maximum nine-quarter cumulative charge-off rate is 5.2%, and the median is 0.70%, with significant variations between good years and bad years.

Figure 8.1 Historical annual gross charge-off rates of commercial banks' CRE loans



Source: FDIC

Figure 8.2 Historical rolling nine-quarter gross charge-off rates of commercial banks' CRE loans



Source: FDIC, Moody's Analytics

This kind of top-down analysis from historical data provides a useful macro view of potential future loss rates and charge-off rates to be expected in base-case and stressed scenarios. For example, if an adverse scenario is similar to the worst recession over the previous two decades and if we have a portfolio similar in composition to the past, then the stressed loss under the adverse scenario should come close to what was experienced in history.

We should emphasise that banks' CRE loan portfolio composition does change from time to time, therefore the pure top-down analysis, while meaningful, will not necessarily reflect the current and future portfolio composition for the banking industry or individual banks. For instance, if a bank historically only underwrote permanent loans with minimum debt service coverage ratio (DSCR) of 1.50 and loan-to-value (LTV) of 60%, its historical loss and charge-off rates

Table 8.2 Summary statistics of CRE loan charge-off rates

	Historical bank CRE charge-off rates (cumulative nine-quarter)
Min	0.14%
Median	0.70%
Max	5.20%
Ratio of max to median	**~7X**

ıld underestimate future credit performance if the bank then ;ened its underwriting criteria to DSCR of 1.20 and LTV of 80%; the same analogy applies to the industry as a whole. To ensure properly stress test the CRE loan portfolio based on the latest tfolio composition, the best approach appears to marry the top-vn macro views with bottom-up loan-level credit analysis. Such a erent modelling framework is discussed in the following section.

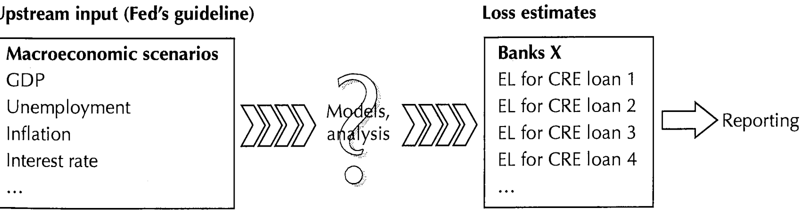
ıR STRESS-TESTING FRAMEWORK AND CREDIT LOSS IMATES

t, let us define the critical problem to be resolved under the AR programme. Given the upstream input (macroeconomic ıarios), the major problem is to develop a credible, transparent repeatable method (models and other types of documentable lysis) to estimate expected losses under the predefined macroeconic scenarios. Figure 8.3 visualises this problem.

ince any useful models are a good approximation for the real rld, let us also think through what would happen (in the real rld) if a severe macroeconomic downturn occurs.

Iacroeconomic demand shocks (as defined in the CCAR and)FAST stressed scenarios) first lead to shocks on the demand for ommercial real estate: when GDP shrinks and firms cut labour, ompanies need less office and industrial space, the unemployed educe demand for multi-family apartments (either double up, ve with family/friends or seek government aid) and people pend less on goods and services, leading to retailers scaling ack retail space needs.

gure 8.3 Models and analysis are required to estimate losses from CCAR enarios



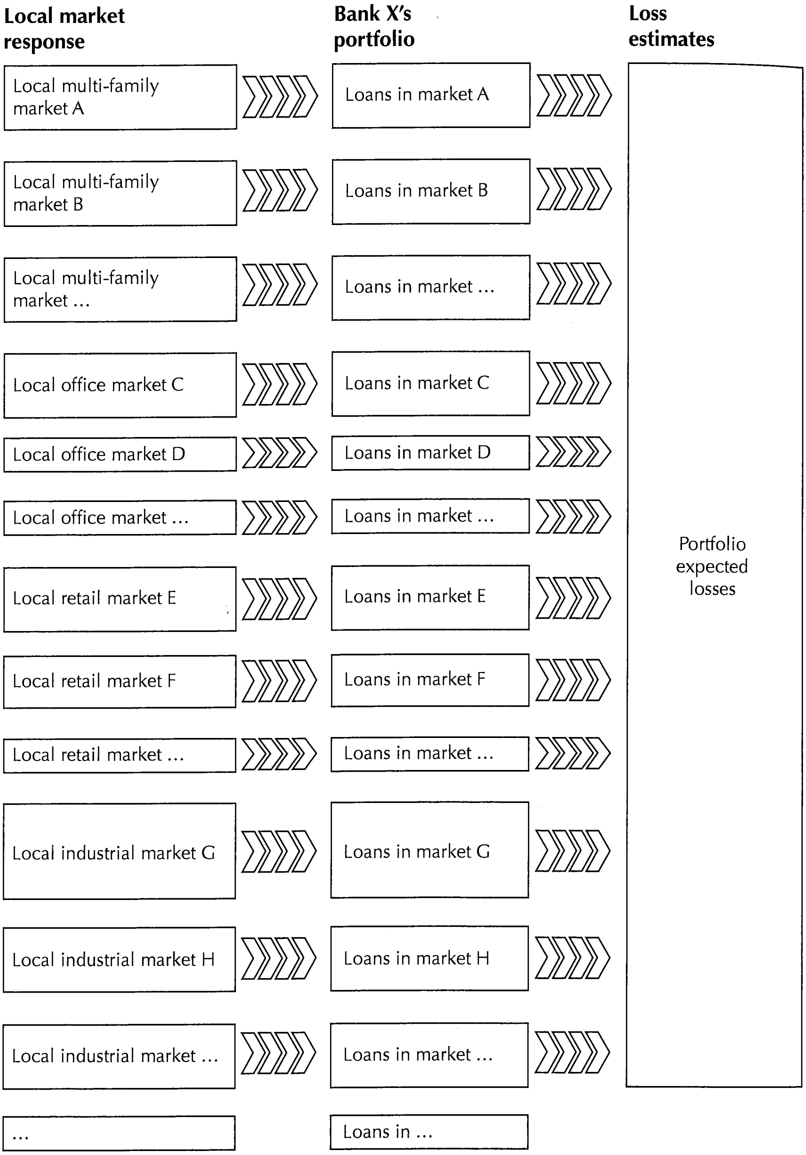
- ❑ Demand shocks themselves may not necessarily trigger CRE market crashes; supply also comes into play, either magnifying or mitigating demand shocks. As discussed earlier, commercial real estate supply is highly inelastic in the short run – ie, little new supply can be added to the market in the short run when demand spikes (long construction cycles required to build large commercial properties). Neither can landlords reduce supply easily when demand shrinks (one has to demolish a property to eliminate that supply in the market, which rarely happens). As such, the current market condition, in particular the supply situation, should also be considered. It is also highly unlikely that the real estate market can reach a long-run space market equilibrium when demand significantly dries up during a severe economic downturn. The vacancy rate is a typical measure used by practitioners to measure the balance between space demand and supply for a given real estate market. As with the natural employment rate, the natural (structural) level of vacancy rate is desired for a healthy functioning real estate space market. When the vacancy rate climbs above the natural level of vacancy, we see declines in rental rates and, consequently, declines in the net operating income of commercial properties.
- ❑ Obviously, real estate properties cannot move from one place to another, making the business about "location, location, location." While one cannot overemphasise the importance regarding the location of commercial properties, it is also true that, in a well-defined local market, many commercial properties are still substitutable commodities. For example, a company or retail store would be perfectly happy to move across the street (assuming no barriers to preventing cars or people crossing the stress easily) if they can obtain nicer space with lower rent. Practitioners typically define a real estate market by property type and location (either metropolitan statistical area, MSA, or sub-market), and within these well-defined local markets, location no longer plays the biggest role. It is the economic and demand/supply conditions that affect the movement of that local market. Following this rationale, for stress-testing purposes, a desirable approach is to quantify and sensitise how local markets will react to macro shocks.
- ❑ While the real estate leasing market is very location-specific, capital is much more fluid. No one is required to buy a particular

property in a particular location. Rather, most investors look typically across wider regions and property types to assess the best buying opportunities given the risks and returns presented to them. Therefore, capital market conditions also affect significantly the valuation of CRE assets and the risks for CRE loans, both from a specific location as well as wider regional/national forces.

- During a recession, vacancy rises, income falls and property value declines. These all lead to an adverse financial situation for commercial properties, making default events more likely. To worsen the situation, it appears that borrowers also behave differently in a stressful environment. It is important for a stress-testing methodology to capture such behavioural differences to ensure that credit events are properly and realistically stressed.
- To further complicate the situation, not only is the commercial property market negatively affected in a recession and borrowers more likely to default, lenders also react to troubled loans differently when the need to clean up the balance sheet is greater. More likely, banks can actually reduce staff when facing a sudden increase in troubled loans. During downturns, special assets that may be handled quickly and satisfactorily during normal market conditions may receive delayed treatment and poorly executed dispositions given the competing priorities and increased workloads in the banks' special assets or other real estate owned (OREO) groups. This change may lead some banks to offload troubled loans at deeper discounted prices than would normally be achieved via an orderly disposition. In turn, this discounting can lead to much higher loss given default (LGD) during a severe recession than would be explained by the decline of property value alone.
- The future is always uncertain, and while the past always provides the best guidance, it is not necessarily the best forecast. For prudent risk management and stress testing, it is also desirable to combine qualitative expert judgement with multiple "what-if" scenarios to quantify the potential impact of a particular model, or models may not fit future market performance.

Such heuristics leads us to believe that a fruitful modelling framework should be designed as shown in Figure 8.4. An important

Figure 8.4 A modelling framework that combines top-down views with bottom-up loan-level analysis



feature of this framework is the explicit use of property type-specific national and local CRE market factors (vacancy, rent, net operating income (NOI) and capitalisation (cap) rate/price). This vertically integrated modelling feature allows macroeconomic assumptions to logically flow through CRE market factors and location-, asset- and loan-level details to enable the most accurate conditional loss estimates under different scenarios.

In this framework, a bank's loan portfolio is analysed at the loan level; a loan's current financial ratios such as DSCR and LTV are linked to local market movements in an economic scenario – therefore, the framework explicitly takes into consideration the local real estate market condition for each individual loan. As this framework is intended to capture the critical causality relationship between macroeconomic drivers and real estate market movements, it offers logical modelling guidance and provides needed intuition, granularity and transparency for business users, senior management and regulators.

TRANSLATING MACROECONOMIC SCENARIOS INTO KEY MEASURES OF CRE MARKETS

National economic and financial measures provided by the Fed in its CCAR guidelines do not, by themselves, directly impact the default and loss behaviours of CRE loans. Rather, these national economic and financial shocks indirectly affect the credit behaviours of CRE loans through the channel of CRE markets.

Under the analytical framework discussed above, as the first step, macroeconomic scenario assumptions must be "translated" into CRE market factors by property type. Furthermore, we need then to estimate local CRE market performance based upon the current condition of each local market and its potential reaction to the macroeconomic shocks.

The key measures or "systematic" factors closely monitored and empirically proven to be influential in commercial real estate markets are:

☐ vacancy;
☐ rent;
☐ NOI;
☐ cap rate; and
☐ property value/price.

The later three measures are strictly related: Cap rate = NOI/value. These measures can respond differently to macroeconomic conditions across different property types. For example, as seen in Figure 8.5, after the financial crisis of 2007–08, the apartment rental market actually recovered fairly quickly, while both retail and office properties continued to have elevated vacancy rates for years afterward, possibly due to expanding internet sales that eliminated storefront needs, and telecommuting, which led to less demand for physical office space.

Given these historical observations, it is clear that we must carefully select the macroeconomic drivers relevant to each property type analysed. It is also important for all the models used in stress testing to capture the fundamental economic causality and dependency of the variables and individual models. For example, some of the models may need to work in an interconnected manner. The vacancy rate first reacts to demand shocks from macroeconomic recession, leading to declines in rental rents. Vacancy increases and rent declines, leading to lower NOI; lower NOI and a potentially higher cap rate (due to higher risk premium) contribute to lower commercial property prices. Such a natural causality relationship must be examined and modelled in a robust system to have clear and explainable economic meanings. We will discuss the key CRE market measures in the following sub-sections.

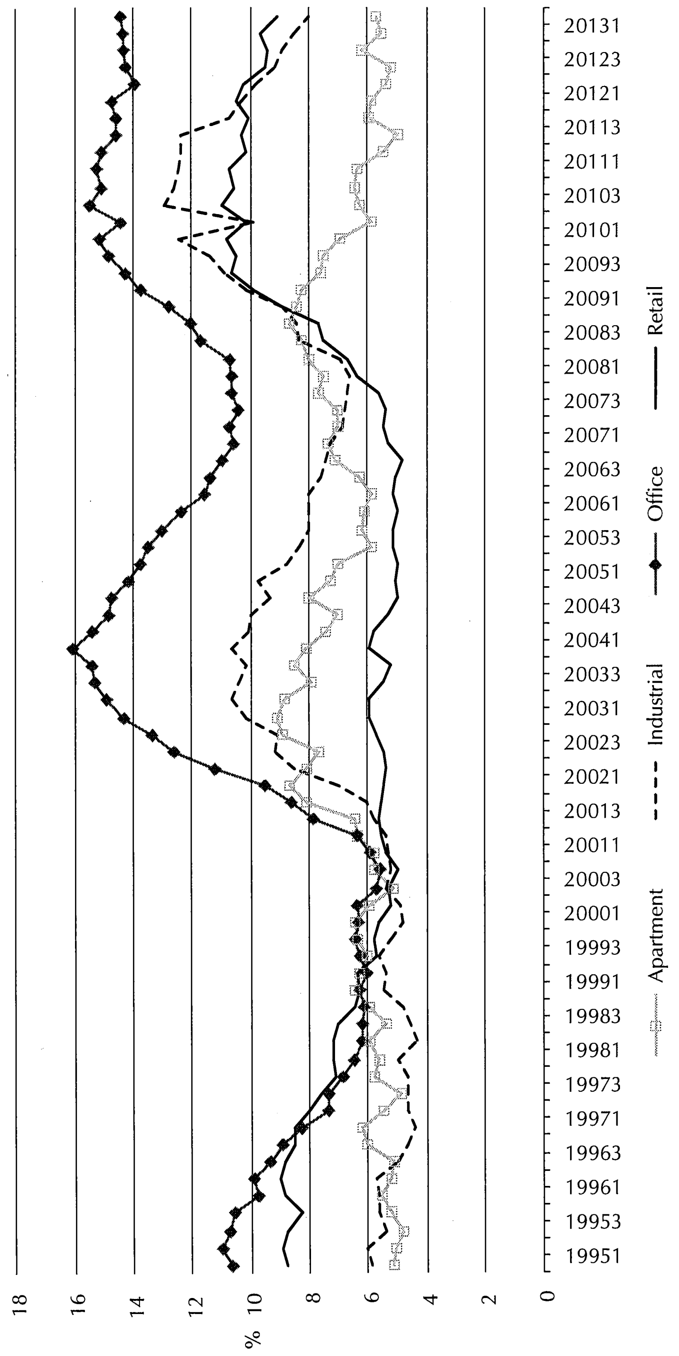
Vacancy

From both a theoretical and empirical perspective, the most important macroeconomic driver of vacancy is the unemployment rate. This greatly influences CRE space demand because lost jobs lead to empty office space, lower consumer spending and fewer hotel stays, etc. As the unemployment rate is a lagging indicator, the CRE market cycle also lags the economy. It takes some time for the economic contraction (or growth) to work its way through the economy to the point where it affects CRE space demand.

Figure 8.6 compares the annual changes in both unemployment rate and national vacancy rates. Historically, they tend to move together in lockstep.

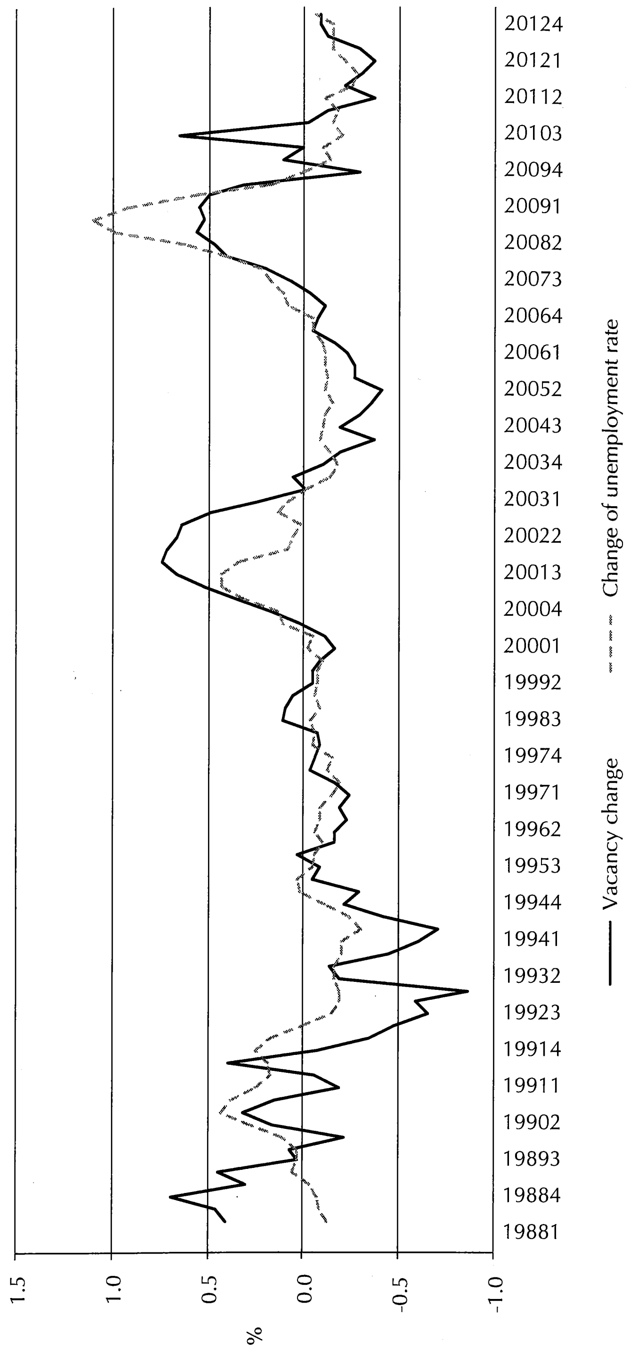
Note, exactly as the unemployment rate has its natural (structural) level, the CRE vacancy rate also has its natural level, where space owners and users find equilibrium in a steady state. In addition, and very importantly, the historical data shows that the vacancy rate reacts to the unemployment rate differently during recessions.

Figure 8.5 Historical vacancy rates by property types



Source: NCREIF

Figure 8.6 Historical relationship between vacancy rate and unemployment rate



Source: NCREIF, Moody's Analytics

During the 2008–10 recession, the unemployment rate increased by 5.4% and the vacancy rate increased by 4.5%, implying an elasticity of 0.8; during the 2001–02 recession, unemployment only increased by 2.2% yet the vacancy rate increased by 5.6%, implying an elasticity of 2.5. The varying degrees of how vacancy rates react to unemployment must be examined carefully when we conduct stress testing for the future. In econometric terms, this is an issue called model parameter stability or regime shift, which must be tested. Sound expert judgement may also be required to determine a final model specification that fits the purposes of stress testing.

In addition to the unemployment rate, other macroeconomic variables can also influence vacancy rates. For example, GDP growth and population growth can also be a factor, depending upon property types.

Rent

While vacancy unavoidably increases during a severe recession, landlords have no better choice but to lower rents in order to entice demand for space. Depending on how much over- or undersupply there is at the onset of the recession, such a rent decline can be either very severe (if already an oversupply before the recession) or somewhat mitigated (if the supply is very tight before the recession).

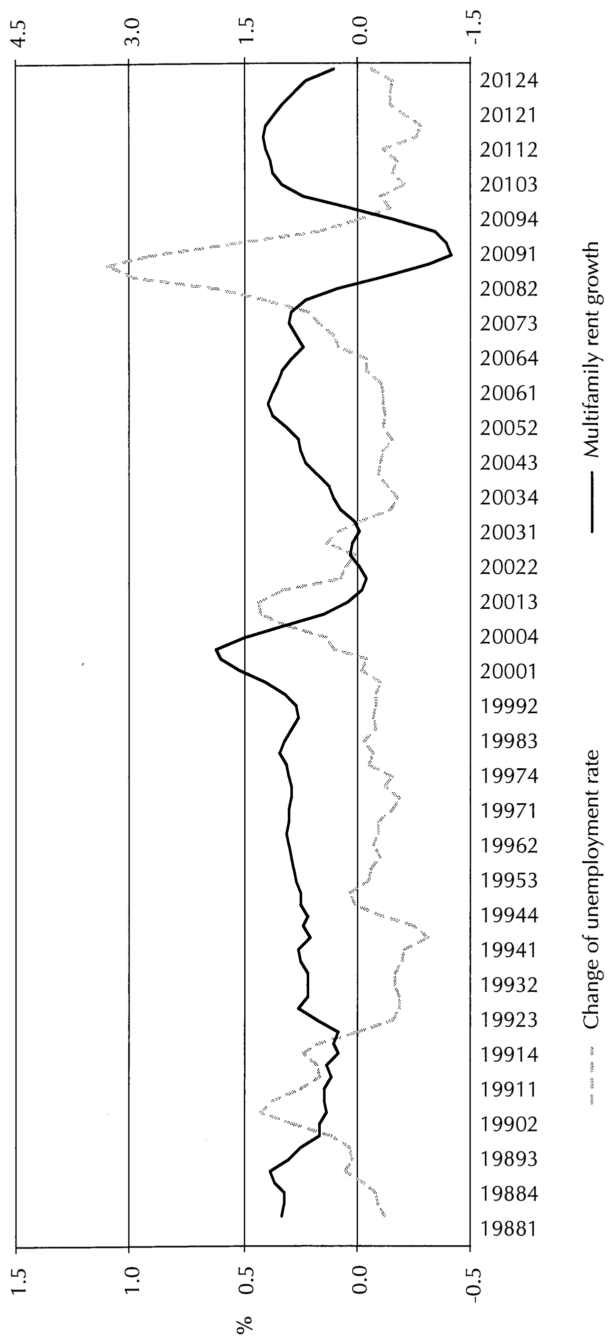
Empirical research shows that, at the national level, rental growth is negatively correlated with the vacancy rate. The example from the multi-family apartment sector also shows the same caveat mentioned earlier (see Figure 8.7), the response function of rental growth rates to change of unemployment rate can vary for each of the historical recessions.

Other macroeconomic variables are also helpful in predicting rental growth for specific property types. For example, retail sales growth has a strong positive relationship with the rental growth of retail properties; non-farm employment growth is positively related to office rental growth, etc.

NOI

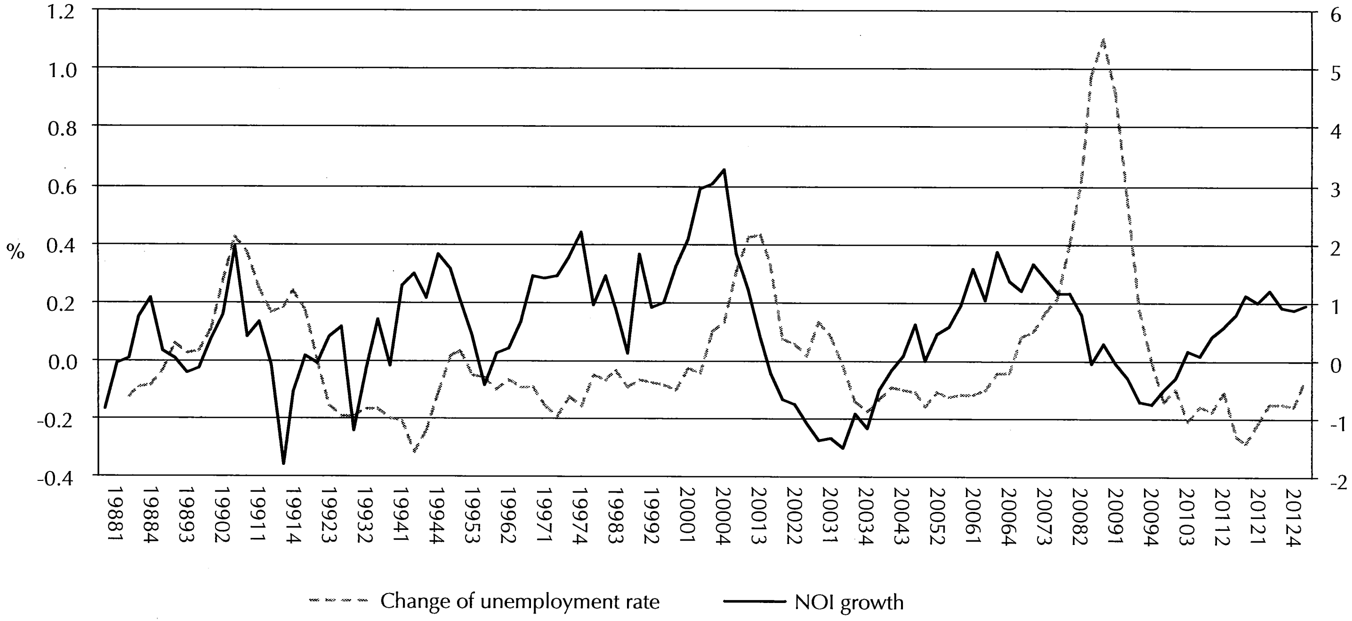
NOI is all rental and other ancillary income minus operating expense. For a reasonably sized commercial property, rental income consists of many leases from various spaces occupied by many different tenants (office suites, retail stores, apartment units, etc).

Figure 8.7 Historical relationship between unemployment rate changes and multi-family rent growth rates



Source: CB Richard Ellis Econometric Advisors (CBRE-EA)

Figure 8.8 Historical relationship between unemployment rate changes and NOI growth rates



Source: NCREIF

Because real estate leases are typically arranged at least as one-year or multiple-year leases, the vacancy change and rental rate declines in recessions would not immediately affect the NOI, rather macroeconomic condition affects NOI in a lagged fashion.

A simple correlation between contemporaneous unemployment rate changes and NOI growth rates is merely –0.08. Meanwhile, the correlation between one-year lagged unemployment rate changes and the NOI growth rate is –0.55, a very statistically significant relationship.

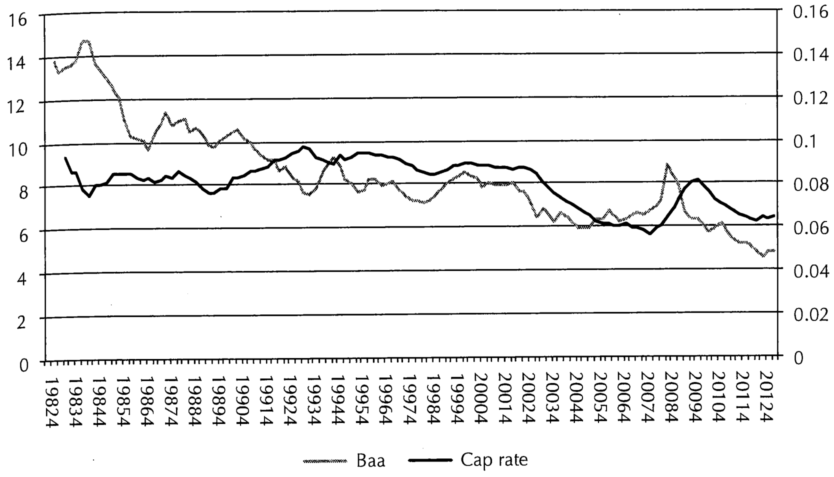
As in the cases of the vacancy rate and the rental rate, other macroeconomic drivers (eg, GDP growth) can also affect NOI growth rates for specific property types. The strength and speed of the relationship between macroeconomic drivers and NOI varies by property type, with the hotel and multi-family sectors being the strongest, the office sector being the weakest and others falling in-between. This finding is possibly attributed to the difference in their lease terms. On the one hand, multi-year office leases lock in rental income for the duration of the lease term, even if the office tenants' actual space needs may decrease in a recession. On the other hand, the short lease term of hotels (one-day stay) and apartments (usually one year) causes rental income to be much more sensitive to economic downturns.

Cap rate/price

The cap rate, defined as a property's annual NOI divided by the property's value, is used as a standard measure or benchmark for a property's value based on current performance. It reflects investor expectations. Similar to bond "yields" or the inverse of PE ratios in valuing stocks, cap rates are a common way of quoting observed market prices for CRE assets in relation to the current income-generating capability of commercial properties. Figure 8.9 shows the historical cap rates and Baa-rated bond yields.

As an example, while the relationship between Baa bond yields and cap rates has varied since the early 1980s, between 1993 and 2002 the correlation between Baa bond yields and the cap rate was 0.72, a highly significant correlation. The reason for positive correlation was that CRE is priced in the capital markets as an alternative to other investment asset classes, including stocks and bonds. The movement of both risk-free interest rates and risk premiums affects all asset

Figure 8.9 Historical relationship between Baa bond yields and cap rate



Source: NCREIF, Moody's

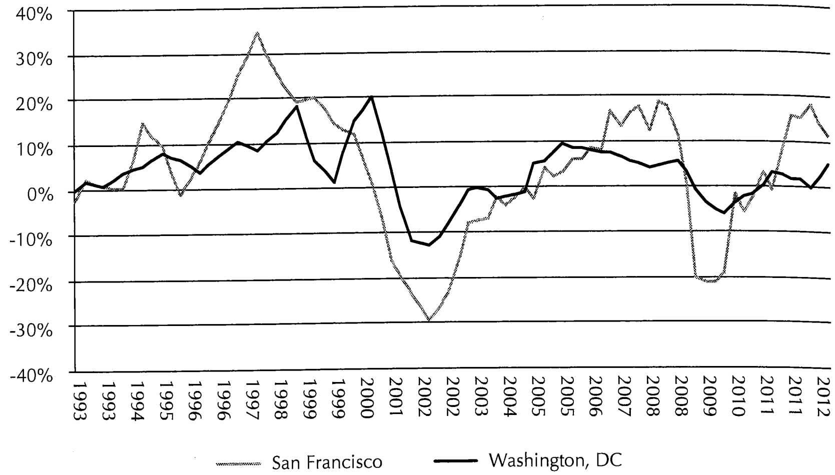
classes, driving positive co-movement of asset prices. Such a relationship is important for CCAR-style stress testing, in that the CCAR macroeconomic scenarios provide explicit assumptions on BBB (equivalent to Baa) bond yields, which can provide useful information in addition to the space market variables (vacancy, rent and NOI) that directly measure the income-generating capacity of commercial properties.

CCAR guidelines also explicitly provide guidance on the overall commercial property price changes under each of the prescribed scenarios, lessening some of the burdens for banks to project the general commercial property price changes under different scenarios. However, since the guidelines have not so far provided details of commercial property prices by property types, a critical dimension in the CRE markets, financial institutions must still develop specific models to estimate possible different commercial property price movements by different property types.

Location, location, location

Location is crucial to real estate, and local CRE market information is crucial to the success of stress testing. Figure 8.10 compares historical office rental growth in two metropolitan areas, Washington DC and

Figure 8.10 Historical office rent year-to-year growth rates



Source: CB Richard Ellis Econometric Advisors (CBRE-EA)

San Francisco. Since the early 1990s, office rental growth in Washington DC has been much less volatile than in San Francisco because the office market in the former is largely dominated by businesses catering to the federal government or is used directly by the agencies; the San Francisco market, on the other hand, is determined primarily by much more volatile industries, such as technology and financial services.

Given the significant regional differences and the difficulty in predicting *ex ante* which region would decline most during the next recession, it would be good practice for banks to conduct "what-if" sensitivity analysis by magnifying selected regional CRE market declines, either on a targeted or a randomised basis. This kind of regional sensitivity analysis is particularly helpful for lenders that specialise in a particular geographic region or property type.

QUANTIFYING THE DEFAULT AND LOSS RATES OF CRE LOANS UNDER A STRESSED SCENARIO

After we have appropriately translated the macroeconomic assumptions into the direct CRE measures by property type and location, the next step is to estimate credit losses for the CRE loan portfolios based on loan-level data such as DSCR and LTV, among many other loan characteristics. For CRE loans, the main credit risk measures are probability of default (PD) and LGD. EL is the product of PD, LGD and the outstanding loan balance at the time of loan default.

For income-producing CRE, as the name suggests, it is first and foremost the income adequacy and variability that drive CRE loan credit risk. The income adequacy is measured by DSCR, and the quality and variability of the income depends upon the property type and location, as well as property-specific idiosyncratic characteristics such as existing lease rolls, property vacancy rate compared to the surrounding local market vacancy rate, whether the in-place rents are above or below the comparable market rents for similar properties, and the creditworthiness of the in-place tenants. Since property appraisals notoriously either lag behind the market or are not sufficient, it is usually good practice to use the stabilised NOI with the market-wide cap rate to determine a market-based property value as a complement to the appraisal value.

A credit event for a CRE loan usually happens when NOI is insufficient to service the mortgage payments, and when the property value is worth less than the unpaid loan amount. A simplified "double-trigger" default rule can be summarised as in Table 8.3

Empirical data must be used to calibrate the real-world default probability for loans in each of the above zones. The frequency and severity of credit events also differs by loan purpose and by whether the loan has reached maturity or not. Next, we discuss the specific drivers for each risk category.

Term risk

Term default is a missed payment before a CRE loan reaches its maturity. Before loan maturity, the borrowers typically only pay periodic mortgage payments, regardless of the underlying collateral value. It has been observed empirically that default risks are driven mostly by insufficient cashflow to cover mortgage payments,

Table 8.3 Stylised default probabilities by financial ratios

	Positive cashflow after debt service	**Negative cashflow after debt service**
Negative book equity	No default	Default
Positive book equity	No default	May or may not default

measured by the DSCR. When DSCR is less than one, the periodic income from the property is insufficient to cover the monthly loan payment, placing the borrower in a precarious financial situation: the borrower must either dip into reserves or other resources to service the debt, or they must sell the property to repay the entire loan. On the other hand, a rational borrower should never default on a CRE loan if DSCR is greater than one (when NOI is more than enough to service the mortgage payment), because the value of the equity option by holding onto the property is always positive prior to loan maturity.[7]

Research has found typically that the loan-level risk drivers are:

- local market (property type and location);
- DSCR;
- LTV;
- loan payment structure;
- collateral and lease characteristics;
- tenant quality and rent rolls;
- loan seasoning;
- capital expenditure (affects net cashflow, NCF);
- borrower/sponsor credit strength; and
- terms and conditions on guarantee and resource.

Historical data also finds that interest-only loans carry more credit risk than fully or partially amortised loans, and, by incurring more interest rate risk, floating rate loans experience more defaults than fixed-rate loans. Furthermore, the seniority of loans makes a big difference. Being at the first-loss position, a junior note has significantly higher loss severity when compared to a senior note.

Maturity risk

Maturity risk mainly includes the refinancing risks that become relevant at loan maturity. Commercial mortgages are subject to substantial maturity risk given that most commercial mortgages are arranged to have a large lump-sum balloon balance at loan maturity, and the prevailing market condition at time of loan maturity may pose significant challenges for the borrowers to refinance the remaining balloon balance from the existing lender or another lender. For instance, the NOI of an underlying property may be just sufficient to cover the debt service (say 1.0). Therefore, the borrower would not default on the mortgage before the loan matures. However, when the loan matures, very few lenders would underwrite a new loan at a DSCR of 1.0, thus increasing the default probability of this matured loan. Another example is, in the middle of the term, a borrower with 0.95 DSCR and 95% LTV is highly unlikely to default on a mortgage payment despite the fact that they may have to use other financial resources to make the mortgage payment whole; at loan maturity the same borrower with the same financial situation is much more likely to default. Furthermore, the lenders would also impose much more restrictive LTV criteria when underwriting a new loan such that even an "above-water" mortgage (say a 80% LTV loan) may not qualify for refinancing, further complicating and increasing the likelihood of default for such a maturing loan.

The main factors driving refinancing risks are:

- ☐ prevailing mortgage rates at loan maturity;
- ☐ declined value or income for the property; and
- ☐ tightened underwriting criteria in the forms of higher DSCR and lower LTV requirements.

In addition, from time to time after a recession there is typically some level of consolidation among lenders, and some lenders experience a larger share of the credit losses. This reality can potentially lead to a reduced number of lenders remaining active in the CRE financing business during or after a severe recession. During the financial crisis of 2007–08, the CMBS market completely dried up, significantly limiting refinancing options for many otherwise-qualified CRE loans.

Construction loan risk

Evaluating credit risk for a construction loan is quite different than evaluating risk for a permanent loan. Besides measurable quantitative factors, many more qualitative factors affect a construction loan – for example, whether the sponsor has the experience to complete a project on time, the sponsor's own credit history, guarantee/recourse clauses and local market knowledge all come into play.

As in the case of income-producing permanent loans, our research has shown that it is most fruitful to apply a Monte Carlo simulation framework to analyse the credit risks of a construction loan for the purpose of CCAR stress testing. In the real world, when a lender agrees to fund a construction loan there is always an assumption of the property's market value at project completion, and implied rental and net operating incomes. These assumptions are typically captured as a "as completed" or "as stabilised" value. For example, a newly constructed office building currently costs developers US$18 million to build, but may sell for US$20 million in the open market. Either explicitly or implicitly, there is an assumption regarding the expected rents and NOI for that new office building. For example, the lender may agree to a US$1.6 million expected NOI each year, which essentially places a cap rate of 8.0% for that new office building. The project may take a total of two years to complete and stabilise, which means that the construction lender expects the borrower to secure additional permanent financing after two years.

Aside from the qualitative factors, the main credit risk of this construction loan is whether or not the projected "as stabilised" (or "as completed") market value of US$20 million and expected NOI of US$1.6 million would actually materialise to enable a smooth transition for the borrower to secure a permanent loan. Many risks exist during the two-year construction loan term. The local real estate market may deteriorate as the economy continues to evolve, or more new projects may suddenly arise that would depress the expected rents and NOI, leading to a lower market value of the proposed project. Another risk involves the proposed property offering less amenity or quality than initially envisioned. This change could lead to lower rents, NOI and value, even if the local market condition does not deteriorate. These risks can be quantitatively modelled, and the modelling techniques of these types of uncertainties appear to fit naturally within a structural Monte Carlo simulation framework.

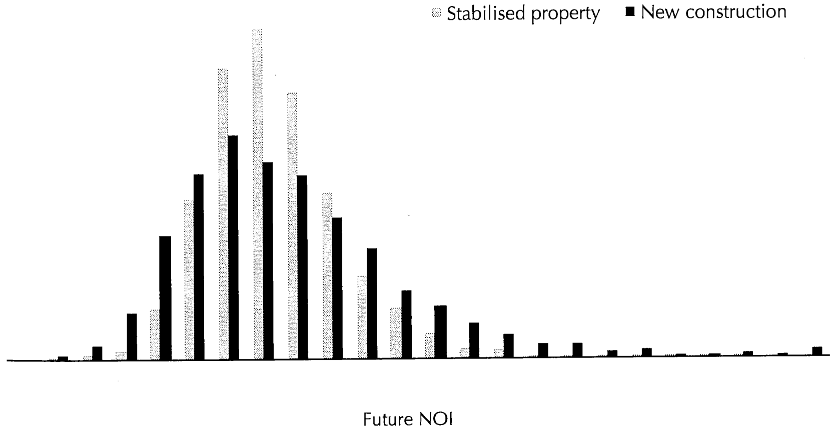
Compared to a permanent loan that finances existing properties, there are some key distinctions with a construction loan: a new construction would not have actual rental income or NOI to begin with. Therefore, the analytical process must begin with the assumptions of "as stabilised" LTV and "shadow" NOI. In the example above, we use the projected US$20 million "as stabilised" value and US$1.6 million NOI as the starting value. Then, the Monte Carlo simulations derive the probabilities of market rent and value eclining during the next two years that lead to a credit loss. onditional upon realisations of simulated property income and alue, we can then estimate empirical-based default probabilities nd loss severities. In the absence of interim operating income and a inimal risk of term default/prepayment, we find that this modeling approach works very well.

At loan maturity, when a construction loan must be paid off in its ntirety, construction loan default risk is mainly a function of LTV nd, to a lesser extent, "implied" DSCR, in addition to local real state market factors. The future NOI for a new construction fluctutes typically much more than a stabilised property because there is o stable existing tenant base. This NOI, which is the cash-generating apacity, directly affects a new construction's value.

Figure 8.11 illustrates a sample comparison of NOI distributions at ne two-year horizon between a construction property and an xisting, stabilised property. As shown, in a typical case our simulaon shows wider NOI distribution for a new construction as ompared to that for an existing, stabilised one.

Given the higher uncertainty of future NOI/value for a new onstruction, most lenders try to mitigate such uncertainty by equesting some level of pre-leasing for new construction projects. Vith pre-leasing in place, the uncertainty of future rents and NOI

Figure 8.11 Comparison of NOI distributions at the two-year horizon: construction property versus existing property



does not necessarily have to be greater for a new construction than for an existing property. To the extent that a pre-leasing agreement is fully enforceable, leasing risk could be significantly reduced and so is the default probability of construction loans. For stress-testing purposes, it is also prudent to factor in the probability that some pre-committed leases may not come to fruition if future tenants failed or are simply unable to execute their pre-leasing commitments during a severe recession.

LGD

Once a loan defaults, the lender enters a work-out phase: it must either restructure/modify the loan, conduct a note sale or foreclose on the property, put it into REO, and then dispose of the property. In a stressed economic environment, a foreclosed property cannot typically achieve the same market price as a comparable performing property, making losses for the bank even higher: the property price would be depressed in a recession, and the foreclosed property price would be even less.

LGD is highly correlated to LTV if the value of the collateral property is correctly estimated. However, this is not always true. In fact, most times it is not true, as the true market price of a commercial property is not fully revealed until it goes on the market and has received buy offers. Appraisal values (mostly lagged, only done when the loan was originated) offer typically very limited information in regard to the sales prices of the underlying collateral if a loan defaults. This makes estimation of loan-level LGD extremely difficult *ex ante*. That said, a pool-level LGD in the stressed environment, on the other hand, is much easier to estimate with a higher degree of accuracy.

State foreclosure laws also make a big difference. In some of the judicial foreclosure states, such as Florida or New Jersey, very lengthy foreclosure processes can add significant costs to the LGD for loans defaulted in these states.

How a financial institution manages troubled commercial property (eg, restructures, forecloses) makes a big difference as well. Management expertise and skills can potentially limit the magnitude of losses. If supported by documented historical evidence, it is possible that a bank can have an internal LGD lower than the industry average experience for the same types of loans.

HOW TO VALIDATE STRESS-TESTING MODELS

Given the highly quantitative nature of CCAR stress testing, it is not surprising that a vast majority of financial institutions have a set of quantitative models that estimate credit losses. In addition, the use of quantitative models requires some level of model validation. Unlike testing a machine's quality by repeating exactly the functions it is supposed to perform, validation of predictive econometric models is both theoretical and empirical, and requires both expert judgement on the economic rationale and actual out-of-sample model predictiveness. A good, rounded model validation should consist of several key aspects. First, one must make sure the signs of the model coefficients do not violate economic intuition. Second, a model robustness check should be performed over sub-samples and across time. Third, one should conduct out-of-sample tests to validate model performance. Last, but not least, sensitivity analysis is particularly helpful in the context of CCAR, given the hypothetical nature of macroeconomic scenarios. This last point can also serve as a very effective communication tool that explains the linkage between key model inputs and model results across a wider audience, which includes model developers, business users, bank executives and regulators.

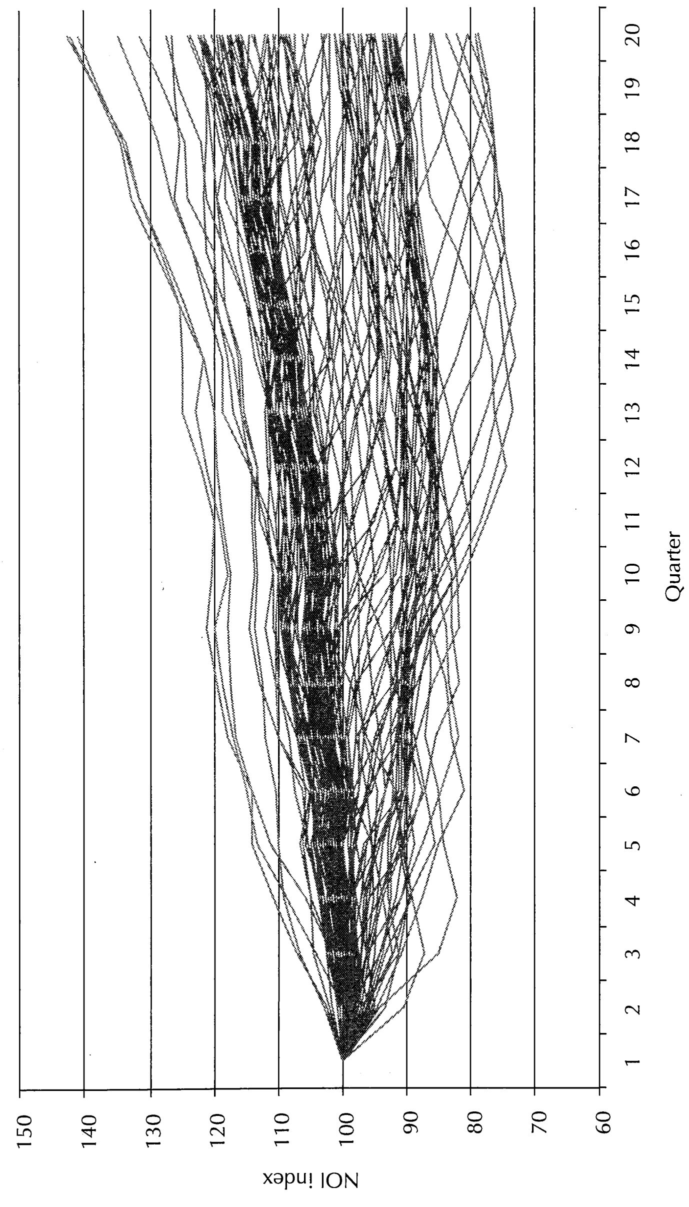
A very good and intuitive way to test a model's performance is by running historical scenarios to examine if the model outcome is consistent with what happened historically. This method basically tests the model by asking some simple and intuitive questions.

☐ What if the Great Recession of 2008–09 occurs again?
☐ What if the recession triggered by the tech bubble occurs again?
☐ What if a stagflation scenario occurs?

These types of questions can be easily understood by business users, and be quite effectively communicated and explained across management and business units.

As an example, Moody's Analytics has developed a CRE loan credit risk model, Commercial Mortgage Metrics (CMM), to address CCAR stress-testing needs. By inputting the historical macroeconomic realisations (over the past 50 years) as future macroeconomic scenarios, as part of the output CMM can generate future NOI scenarios corresponding to each of the future macroeconomic

Figure 8.12 A sample of NOI distribution through Monte Carlo simulations



Source: Moody's Analytics

scenarios. The results show that the model outcome, in terms of both the median trend and upside/downside, is broadly consistent with the CRE market performance observed historically. That is, the NOI decline could be as bad 20% within two years and could be close to 25% over three to four years – similar to historical declines during the worst periods. Other variables, such as value declines, vacancy changes and resulting PD/LGD/EL measures, can all be examined in similar fashion.

Financial institutions and regulators can benefit by conducting similar exercises to examine their model robustness and sensitivity. In the meantime, senior banking executives who may not be trained in quantitative statistics can easily assess the reasonableness and usefulness of the model from such an exercise.

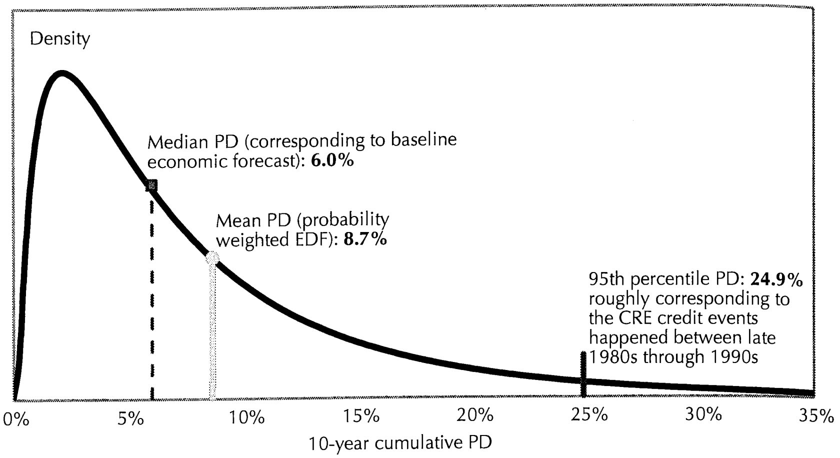
Furthermore, to effectively measure and manage credit risks, banks also want to input hypothetical macroeconomic scenarios as in the flavour of CCAR to obtain a full distribution of credit risks.

INTERPRETING SCENARIO-BASED MODEL RESULTS

Modellers and senior management need appropriate ways to interpret credit loss estimates from various models in order to understand the limitations of the models and to mitigate/manage model risks if needed. A known statistical credit loss distribution property is its right-hand skewed, fat-tailed distribution. Credit losses cannot be negative, while the upper limit is 100% of the exposure. In the meantime, credit events are rare events with a low probability of occurring, meaning the expected default frequency and expected loss is typically in the low single digits (or less), measured on an annual frequency. This stylised pattern is shown in Figure 8.13.

Figure 8.13 depicts a distribution curve of conditional PD measures for a typical commercial mortgage, covering a full range of all possible economic scenarios. Each point on the curve corresponds to a conditional PD estimate for an underlying economic scenario. Note that this figure does not include the idiosyncratic variation. Hence, one can also interpret it as representing the distribution of default rates for a very well-diversified portfolio of commercial mortgages when the single risk driver is the market/economy.[8] At this point, it is useful to be aware of the following important observations.

Figure 8.13 Credit loss distribution and points of median, mean and stressed percentiles



- ❑ The median PD, while usually corresponding to the baseline economic forecast, is almost always less than the unconditional expected default frequency (EDF credit measure) integrated from all possible economic scenarios. The importance of this statistical property is such that users should always be aware that the conditional PD and EL measures from a baseline scenario should not be used as if they were unconditional expected (mean) measures. In fact, using conditional PD and EL measures from a baseline scenario always understates the true risks, although the magnitude of such understatement varies by loan characteristics and market volatilities, among other things.
- ❑ For a typical commercial mortgage, it is possible that the unconditional expected (mean) measures of PD can be significantly higher than the median PD measure. Our example, which describes a typical mortgage, suggests that the unconditional expected PD measure can be 1.45 times the median measure. In other words, for the purposes of loss forecast, loss reserve and loan pricing, users should use 1.45 times the median PD measure (ie, PD estimated from a baseline economic forecast) if a PD from the baseline forecast is the only input into the decision process.
- ❑ The tail risk is "fat," and default rates can be exponentially higher during a stressed economic environment. One should not

use a normal distribution proxy as a shortcut. In our example, the 95th-percentile conditional PD is measured at 24.9%, approximately four times the median PD and three times the mean PD. Such heavy tails on the right-hand side explain why the mean PD can be significantly higher than the median PD. From the perspective of business intuition, the 95th-percentile economic scenario roughly corresponds to the CRE credit events that occurred between the late 1980s and the early 1990s, during which the default rates and loss rates skyrocketed when the CRE market vacancy rates soured, leading to severe declines in rent, income and market price. This experience was somewhat echoed by the severe CRE market deterioration during the financial crisis of 2007–08, during which commercial property prices dropped by more than 40%, accompanied by rising vacancy rates and declining rents. The two "market crash" events happened within a window of about 30 years, lasting a few years each, so a 95th-percentile is consistent with the history in a broad sense.

Expected loss, unexpected loss and mitigating overlay

Note, even if the banking industry as a whole possesses adequate capital to absorb the aggregate expected losses from the stressed scenario, some individual banks may still fail due to the natural distribution of realised losses around expected losses. This reality poses an important question to both regulators and financial institutions, in that aggregate capital adequacy may not help individual banks during a severe recession. Table 8.4 shows an example of how easily this could occur.

In this example, suppose the banking system is composed of three

Table 8.4 A sample of expected and unexpected losses

Bank	Expected loss under severely adverse scenario (US$ billion)	"Realised" loss under severely adverse scenario (US$ billion)	"Unexpected" loss ("realised" – expected)
A	1.10	0.90	–0.20
B	4.60	3.60	–1.00
C	2.30	3.50	1.20
Total	**8.00**	**8.00**	**0.00**

banks. We estimate expected losses for all three banks and find the total to be US$8.0 billion under a severely adverse macroeconomic scenario. In addition, very unfortunately, suppose that a severe recession hits the economy, and the recession turns out to be as severely adverse as prescribed. Furthermore, suppose that the realised losses for the banking system turn out to be exactly the US$8.0 billion as predicted. In this case, the entire banking system is adequately capitalised, but a problem surfaces for bank C, because the realised loss for bank C turns out to be a lot larger than *ex ante* expectations. Note, this is not necessarily a remote event in reality, and does not in any way suggest that the research and analytics are necessarily poor in estimating the expected losses for individual banks. Rather, the fact remains that credit loss estimation is difficult, and any expected results are subject to errors. If compounded by borrower default behavioural shifts and potential individual banks' mismanagement during the recession, then it is very possible that an individual bank, in our example bank C, experiences larger realised credit loss than expected.

This example can be easily generalised in the real world, where the banking system is made of dozens of large CCAR banks and thousands of small banks. At the time of writing, we have not seen an explicit methodology or guidance from regulators on how these "unexpected" losses should be accounted for. It appears that estimating expected losses correctly has consumed most of the regulators' and banks' efforts. This a natural process, as we cannot jump into the "unexpected loss" concept without first getting the "expected loss" correct. However, after regulators and banks become comfortable with the expected loss estimation part, it may be time to think through the next important issues surrounding unexpected losses and unexpected events that could cause some banks to fail.

Even without explicit regulatory mandates, it can help banks measure and manage capital better by providing overlay of additional sensitivity analysis to quantify the unexpected losses for particular property types or regions where a bank has high CRE concentration. For example, while historically multi-family properties always perform more stably than office properties, and we expect this trend to continue going forward, it would not hurt to assess the "unexpected" impact under a "what-if" scenario where multi-family properties become as volatile as office properties. This type of exercise offers particularly useful information on the vulnerability of the assumptions, and should be encouraged. Furthermore, once some material vulnerability has been identified and quantified through such exercise, it would then make sense for individual banks to add an appropriate capital buffer to account for model risks despite otherwise perfectly sound models.

CONCLUSIONS

Given the CCAR macroeconomic scenarios, we propose a structural framework to estimate credit losses for CRE loans. This framework intends to mimic the logical sequences that occur in the real world should a recession happen. It uses macroeconomic assumptions as the upstream inputs and then translates macroeconomic assumptions into the key drivers in CRE markets, which are then used to predict credit losses by incorporating loan-level details, including financial ratios (DSCR and LTV), as well as property type and location specifics. By establishing a strong economic causality relationship between credit risks and macroeconomic-, real estate market- and property-specific covariates, this framework enables large-scale scenario analysis and stress testing in a logical, transparent and repeatable fashion without sacrificing model granularity and accuracy.

Given that the framework is relatively sophisticated, it also potentially opens the door for unintended misinterpretation of the scenario-based risk measures. We highlight the key areas requiring attention and additional overlay/sensitivity analysis. As discussed throughout the chapter, if one can skillfully harness its power, the proposed framework can provide accurate expected results conditional upon certain economic scenarios, as well as provide additional insights for multiple "what-if," unexpected risk analysis.

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1 See Office of the Comptroller of the Currency *et al*, 2006, p. 6.

2 See Federal Reserve System, 2011, p. 11. The sample principle was followed in the later CCAR programmes.

3 The definitions listed here are from the Federal Reserve FR Y-9C and FR Y-14Q templates and instructions.

4 For owner-occupied CRE, LGD may still be very much related to the underlying CRE collat-

eral, hence a hybrid approach may be optimal. This follows, because if a borrower defaults on an owner-occupied CRE loan, the residual value of the collateral should be roughly the same as if the collateral can be leased as an income-producing commercial property.

5 Historical and current datasets can be downloaded from the FDIC website (http://www2.fdic.gov/sdi/main.asp).

6 EL is an economic loss concept, while charge-off is more of an accounting loss concept. Although the two mainly differ in the timing of loss recognition, ultimately they should roughly match on a cumulative basis.

7 Here, we should note that so-called "underwater" mortgages in popular media do not equal negative option value for the borrowers. "Underwater" by popular definition simply refers to the book value of the equity being "negative," yet the true market value of the equity option should always be positive, unless the debt has reached its maturity.

8 To help interpret the figure better, maybe it is easier to think of this as equivalent to a probability density plot of the returns of S&P 500 index instead of a plot on an individual component, such as Microsoft.

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9

Stress Testing and Retail Portfolios

Soner Tunay and Rosa Català

Citizens Bank

Loss forecasting for consumer products has been practised by many leading institutions for a long time. However, regulatory demands have expanded this process by linking forecasts to macroeconomic drivers, integrating them into an enterprise-wide exercise and further using the forecast results as an assessment of capital adequacy. Stress testing embodies two aspects: a macroprudential supervision aspect, allowing regulators to gain a horizontal view of the banking system; and a microprudential risk assessment aspect, for banks to assess their own product and portfolio risk. The best application of the stress-testing framework in financial institutions will at least satisfy the regulatory requirements, and extends the use of the framework to business applications. This chapter will discuss the application of stress testing for consumer portfolios both from a methodology and firm-wide application standpoint, and is aimed at practitioners and modellers, including risk professionals and the portfolio managers.

The design of the framework here is limited to the assets side of the balance sheet, in particular to loans and credit lines such as cards and home equity lines of credit. While the Comprehensive Capital Analysis and Review (CCAR) exercise requires the liabilities to be jointly analysed with assets, the major challenge for the industry has become to capture the loss and revenue analytics of the assets sufficiently well. Although the same modelling philosophy applies to liabilities, the implementation of the framework as illustrated here is limited to the consumer assets.

The chapter is organised as follows. The next section introduces the integrated stress-testing framework. The features of data and model design are explained in the third section. The fourth section covers the technical aspects of estimation methodology. The last section illustrates the application of the framework, and concludes.

The going-concern view in risk management has brought new meaning to what forecasting means for retail stress testing in financial institutions. Income and loan loss forecasting have always been important risk management and consumer finance functions in banks. Their significance is reinforced by the central role of the macroeconomic-driven stress testing. This regime requires a brand new approach to retail portfolio analytics. In this renewed forecasting approach, both losses and revenues are jointly forecasted. It is fair to say that the new approach requires interactions between the business units, such as risk, finance and product managers, where both product risk and business strategy are captured and embedded into the projections.

The challenges in building a comprehensive and overarching framework will not only be the modelling issues, but breaking the status quo of fragmented approaches across the firm, retiring older-generation piecemeal, disconnected models and overcoming silent barriers between various divisions within a bank.

This new consumer stress-testing framework also challenges some of the traditional analytical approaches to measure and manage credit risk. In particular, modelling for business purposes encourages: (i) a multi-period approach rather than the one-year period (as in the Basel II A-IRB models); and (ii) the incorporation of new business activity as a central part of the exercise in order to capture the dynamic evolution of credit risk in the banking book. Those two perspectives introduced by a comprehensive and integrated stress-testing approach contribute to the managing of credit risk actively using a risk identification and risk mitigation approach, in which new loans are incorporated into the existing book following the underwriting standards and business strategy.

FRAMEWORK

A truly risk-aware active balance-sheet management system and a successful stress-test framework design are very much alike. Essentially, with an integrated stress-testing approach, a bank implements an analytical framework by which many of the future projections regarding the balance sheet – including loss, revenue estimates and strategic decisions – could be made; the risk and blind spots are clearly identified, and ultimately decisions are made with full knowledge of the business and product strategy. A stress-testing framework should not be seen solely as a risk quantification or modelling exercise – it is the integration of risk within the business uses and interaction between key divisions of a bank, including risk, finance and portfolio managers.

Features of the framework

A framework that can serve as the risk roadmap for business purposes and at the same time satisfy the regulatory requirements should have the following features.

- ☐ Bank-wide implementation: multiple divisions within the bank (risk, treasury, finance and business units) collaborate to establish the framework.
- ☐ Comprehensive product coverage: the same macro scenario is applied to all assets and the same methodology is used for loss and revenue projections.
- ☐ Integrated approach: interaction between loss drivers and factors influencing revenue generation process is captured simultaneously.
- ☐ Macroeconomic linkages: stressful scenarios are described by adverse macroeconomic conditions, such as unemployment, housing prices and gross domestic product (GDP).
- ☐ Product-specific characteristics: analysis of each individual product (ie, mortgages, credit cards) that is linked to economic conditions and its risk factors.
- ☐ Capture bank's internal policy variables: underwriting standards and other strategic initiatives.
- ☐ Multi-period and lifetime view of the product: dynamic changes in a product's life could have different implications for revenue and loss realisations for each point in the future.
- ☐ Use in business decision-making: not only for regulatory or compliance incentives, but also driven to inform budget and planning, sales targets, capital utilisation, etc.

This integrated and comprehensive set of tools might be available in some banks, but are likely to be either owned by various units, or are not sufficiently developed to provide a full picture of risk and return. It is only in the last few years that there has been the ability in the banking industry to analyse the full balance sheet using macroeconomic drivers. It was first tried out in a systemic way in 2009 with the Supervisory Capital Assessment Program (SCAP) exercise conducted by the Federal Reserve. With the publication of the Dodd–Frank Act, it became a regular annual capital assessment exercise.

Stress testing in this integrated and comprehensive form is fairly involved. In this process, regulators and banks are only starting to discover the best-in-class applications. The CCAR regime is an opportunity to think about the limitations of the previous generation's model practices, and be innovative about the next generation of increasingly integrated tools and solutions.

The addition of the term "comprehensive" to the notion of stress testing implies strong reinforcement of the active portfolio management practice. In a truly comprehensive stress-testing methodology, market risks should be jointly determined with credit risk. This analysis should be extended to new originations as well as a lifecycle view of products – all tied together by macroeconomic factors. This is why only an integrated framework can respond to the demands of a comprehensive stress analysis, and can lead to credit risk management, capital planning and also net income analysis.

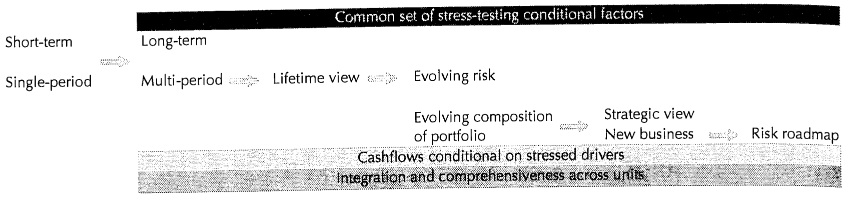
Table 9.1 displays all possible uses of the stress-testing framework across different divisions of the bank for various applications. For each of these applications, a different metric could be used, but the overall framework should be designed to serve multiple purposes from a single source, where interactions among these metrics are established. The end purpose might be revenue estimation for pre-provision net revenue (PPNR), loss forecasts for Allowance for Loan and Lease Losses (ALLL), capital adequacy and return on capital for capital planning, with the ultimate aim of setting the business strategy for the existing portfolio or future acquisitions. All the metrics produced for these purposes would be driven by the same set of macroeconomic variables, and have the same credit policy and business inputs.

Figure 9.1 illustrates how the stress-testing framework is able to deliver a risk roadmap for the enterprise, moving away from the

Table 9.1 Uses of the stress-testing framework

		Forecasting components				Stress-testing conditioning factors				Active portfolio management
		PPNR	ALLL	Capital planning	Business strategy for future business	Economic conditions	Product lifecycle characteristics	Credit characteristics	Strategic efforts	
Comprehensive coverage	Themes	- Forecast of revenue by business segment - Forecast of interest income by product based	Provision levels based on: Forecast of net charge-off rates by product based	Capital ratio projections - Risk appetite - RWAs		Macroeconomic scenarios (regulatory, internal)	Changes in product attributes due to seasoning and aging	Underwriting standards, risk indicators	Regional expansions, appetite for growth, general market dynamics of product, pricing strategies	
	Metrics	**Existing balances**	**Existing balances**	**Existing balances**	**Existing balances**					
		New origination or purchased balances	New origination or purchased balances	New origination or purchased balances	New origination or purchased balances					
		Coupons								
		Weighted average life								
			Charge-off and recovery balances							
			Deliquency balances							
		Capital action plan								

Figure 9.1 Long-term view of stress-testing banking risks


Common set of stress-testing conditional factors
Short-term
Long-term
Single-period
Multi-period
Lifetime view
Evolving risk
Evolving composition of portfolio
Strategic view
New business
Risk roadmap
Cashflows conditional on stressed drivers
Integration and comprehensiveness across units

single-period, short-term vision that has predominated in assessing loan book's risks. As will be discussed, a cashflow-centric view and an integrated and comprehensive vision can effectively translate a stress-testing output into a risk roadmap for managing loan portfolios and, especially, retail exposures.

Retail exposures characteristics

It is easier to build forecasting models with consumer assets than with commercial exposures. Consumer datasets tend to be larger and richer. In addition, individual's responses to macroeconomic shocks tend to be uniform. Therefore, borrowers of retail assets can be grouped into homogenous pools and analysed in cohorts. However, there are certain challenges in building a retail stress-testing framework. Consumer prepayments are more sensitive to interest rates than commercial ones. Moreover, the prepayment percentage of the book is a more sizeable amount in some retail assets such as mortgages, which requires that credit risk needs to be modelled jointly with the interest rate risk in order to fully capture the dynamics of the banking book.

Three important aspects of retail stress testing will now be highlighted.

Multi-period and lifetime view of the product

The lifetime of retail products can be calculated with reasonable accuracy. Even for the most interest-rate sensitive products, prepayments speeds, amortisation, and hence effective lifespan, can be estimated. However, within the same product category, the response to macroeconomic shock can be different, since a cohort of loans would exhibit different behaviours at different parts of their expected life. Once consumer loans are in the book, there is little that can be done, making the characterisation of retail lifetime products very necessary. Also, since consumer products tend to have longer maturities, a full-lifetime view of the product is even more important.

Evolving risk and composition and macroeconomic linkages

Given the above, the retail framework should be able to produce results across various paths in which cashflows are sensitive to the definition of the scenarios. Macroeconomic shocks can alter scheduled amortisations in loans, and when that impact is sufficiently large in terms of the type and number of loans, both the revenue and risk profile of existing loans will change. The timing of the shocks is very crucial for retail stress testing, because the response of the product to the macroeconomic shocks changes over its lifetime depending on the macroeconomic environment. These dynamics make risk and shocks evolve over time, and offer a changing profile for retail exposures that must be monitored and captured.

New business strategy to actively manage retail portfolios

The "stickiness" of consumer loans on books makes new business strategy drive the active management of the portfolios. Stress-testing models should analyse the behaviour of the to-be-booked future loans with the same sophistication as the existing portfolio. After all, the existing portfolio is a foregone concern, with limited actions that can be taken to manage it. Many applications of the portfolio analytics in the earlier generation models failed to capture the ongoing concern of risk, and treated the portfolio of retail products as closed-end funds. However, a bank's origination strategy and its underwriting standards determine future losses as well as the future income stream. Different combinations of FICO (Fair Isaac Company) scores and loan-to-value (LTV) ratio targets could achieve the same loss rates. Combined with other business initiatives, such as marketing and pricing strategy, risk/return maximisation can be achieved. Given the multi-period and evolving risk of consumer loans and lines, these various combinations could lead to very different risk/return profiles under different economic environments.

A risk roadmap can be put in place if the above characteristics are taken into account and supported by an integrated and comprehensive view, enabled by capturing the balance dynamics to test the resilience of the portfolio under adverse conditions. How such a risk roadmap can be enabled, and what to avoid, are discussed next.

What to avoid

One of the common mistakes seen in consumer stress-testing applications is the tendency to use the Basel advanced internal ratings models probability of default (PD) and loss given default (LGD) models. While there might be some exceptions, most of these models offer cross-sectional analysis of risk attributes. Given risk drivers such as FICO scores and LTV ratios, these cross-sectional data models treat a large swathe of customers together (although they appear on the books at different times), and assign a probability to credit events such as default or loss severity that are happening over the following 12 months. The worst implementation of such models are the ones that use multiple cycles and therefore capture an average tendency to default across a long time series and across different portfolio compositions, irrespective of the underlying macroeconomic factors. However, from the recession that followed the financial crisis of 2007–08, we learned that 80% LTV had a different credit risk profile in 2006 than in 2012, as graphically illustrated by Figures 9.2 and 9.3. Failing to put into context credit quality with the ensuing macroeconomic factors would be a mistake in consumer risk analysis and, as argued in the following sections, is not an excuse given the granular richness of the retail data. The best applications of stress-test analytics treat the problem of exploiting the information in rich panels with history of loans that can be clustered and followed over time. The most delicate matter is to determine which aggregation or cluster definition can better gauge the evolving risk profile of the books, as the economy and business strategy change over time. The stress-testing framework is the place where different bank units can discuss strategy and risk using historical evidence and business knowledge.

Another unintended by-product of the Basel models is the one-year risk horizon in the PD, LGD and exposure at default (EAD) models. Most products stay on the books longer than one year, and there has been a lack of consensus in the industry about how to handle the longer time risks in the retail portfolios. The best approach should capture the risks in the product's lifetime, as in lifetime credit losses. Changing market conditions could change the product loss profile significantly, or even impact the business strategy. To illustrate, prior to the housing crisis, banks that originated mortgages mostly did so with the intent of sale. They had little to worry about from long-term default risk. It is commonly believed that mortgage default rates peak around 20 months after origination. If the default models have a limited time horizon, as in 12 months, the risk identification would be incomplete. The future default risk and thus the capital requirements would be much higher if we consider a situation where adverse economic conditions forced the bank to hold these mortgages for their lifetime. Similarly, there has been little attention paid to the exact timing of default and recovery. A high-level model that would measure the default risk only for the next 12 months is no longer adequate for proper stress testing. More precise models of default and recovery are required to build the quarterly cashflows for the CCAR exercise. Hence, the predictions should be at least quarterly steps with a full view of the product's life cycle.

Additionally, stress testing challenges the problem of disconnection among risk quantification efforts by the enterprise, as Table 9.1 illustrated. Traditionally, different units within a bank are responsible for the different parameter estimates being used in various applications. For example, it is often the risk division that builds models to estimate the credit risk. Likewise, it has been the treasury division that has used prepayment and amortisation models to forecast the future balances. A common shortcoming in the application of prepayment models is that they effectively capture the interest-rate sensitivity, but either ignores the credit risk component or builds independently from the models used in risk. In an integrated stress-testing framework, all parameters related to losses or PPNR should be jointly estimated, as credit could be a limiting factor in the determination of prepayments – and, in adverse conditions, they could even be an adverse selection. Failing to capture these interdependencies would lead to imprecise PPNR estimates in CCAR.

Stress testing and cashflows

A very effective way of avoiding the shortcomings of short-term horizons and integrating models across divisions is to have as an output of the framework cashflows conditional on the macroeconomic and other risk factors. Outflows (gross charge-offs, amortisations and prepayments) along with inflows (recoveries, new business) should be captured in a manner that allows the balance-sheet dynamics to be captured. In the implementation sections, it has been shown that consumer data organised under correct quantitative design could help to describe the balance-sheet dynamics.

To control for the consistency of balances and their dynamics in the framework is a way of shifting from a single-period to a multi-period analysis of risk in consumer portfolios, characterised by weighted average life (WAL) and weighted average maturity (WAM) figures that are typically well above a year. As a result, this multi-period approach contributes to the comprehensiveness of the framework. Since all consumer exposures can be subject to the same macroeconomic stress at the same time, jointly determined loss and revenue estimates over the life of the different products should be compared against each other under each stressed scenario. While some stresses would deplete capital reserves because of higher credit losses, earnings could be a source of organic capital growth. This comprehensive nature of the stress-testing framework can then be attained, making cashflows an output of it. Table 9.2 illustrates this, and shows how this cashflow approach is tied to the integrated and comprehensive nature of the framework.

The integrated aspect of a framework that produces cashflows conditional to macroeconomic scenarios is also fundamental to their use by units other than risk. Treasury, finance and even business lines can readily incorporate those cashflows into their current analytics, while incorporating a unified set of stress-testing factors. Going back to the example of prepayments, it is customary that prepayment models are housed in the asset/liability management (ALM) framework, which traditionally are mostly driven by interest rate scenarios. However, as the housing crisis displayed, the ability to re-finance can be curtailed by limited access to credit, and therefore be more important than the willingness to re-finance. An ability and the incentive to refinance should be driven by both market and credit considerations. This is inextricably difficult if the prepayment models are housed in ALM system and loss models are built independently by the risk function.

Another example would be the interaction of losses with the revenues. Assume that the bank is willing to lower underwriting standards in order to increase the yield, but cannot exactly link the risk to the targeted amount of net revenue if loss and revenue models sit in silos and are not driven off the same conditioning factors. There would be many interaction points between the credit aspects and the

Table 9.2 Stress testing comprehensiveness via cashflows

	Existing balances		New originations	Delinquency balances	Charge-off amount	Recovery cashflows	Revenue	Independent variables	
	Prepayment cashflows	Amortisation cashflows							
Historical data	Weighted average life		Lifetime loss and revenue	Delinquency roll rates	NPL rolls	NCO rates and timing of charge-offs	Profitability analysis	Economic conditions Product life-cycle characteristics Credit characteristics Strategic efforts	
	Credit quality and other attributes of existing balances								
Econometric relationships									
								Scenario Definition	
Forecast metrics	Prepayment CF	Amortisation CF	New originations		Charge-off CF			Economic conditions Product life-cycle characteristics Credit characteristics Strategic effors	Forecast data
CFs	Amortising loans: Balance(t) = Balance(t-1)-Prepayment CF(t)-Charge-off CF(t)+New originations(t) Revolving lines: Balance(t) = Balance(t-1)-Prepayment CF(t)-Charge-off CF(t)+New Lines(t)+Change in utilisation(t)								
Forecast themes	Term, interest rate type and product choice		Business strategy and origination quality	Management of the existing book	Credit quality	Collection actions	Revenue and profitability hurdle rates	Variables controlled by the bank	
	Capital management and risk appetite								

revenue-generation initiative. These examples call for an integrated bank-wide solution where the different analytics have a common denominator, and stress-testing cashflows represent a very effective way of attaining such a solution.

RETAIL DATA ALIGMENT AND MODEL SET-UP

The building blocks of the framework in its implementation stage are: (i) a data structure supporting the architecture of the model; and (ii) a quantitative engine. Those two combined must meet the regulatory and business requirements discussed in the previous sections. In this section, data considerations will be reviewed in what is considered the backbone of the overall architecture of the model. These considerations concern the challenges and opportunities of working from loan-level data, its aggregation and, finally, its combination with forecasts.

In particular for retail exposures, the proposed stress-testing framework starts with internal data at the more granular level, ie, the loan level, and the time series recovered by retrospectively tracking each loan account. A rich historical panel data structure in which historical macroeconomic performance and bank's internal performance has to be reconstructed so that it can be effectively matched in the econometric engine. This involves challenges, but also opportunities to gain insights in deciding on the model set-up. Forecasts of stress-testing conditioning factors such as credit policy, product strategy and business growth will be lined up and linked using the quantitative engine. Each set of informational elements, which are presented in Table 9.3 for both historical and forecasting purposes, are considered next.

Data challenges and opportunities in gathering the history of loans

Bank's internal data for a retail stress-testing framework, particularly in its cross-sectional dimension, are very rich and granular. Only such internal data are able to capture specific customer, geography and portfolio characteristics, and the business activities of the institution. The data also offer flexibility in terms of segmentation and aggregation, and therefore to tie exposures to the right macroeconomic variables. A complete coverage of the portfolio balances is a standard minimum requirement set by both regulatory and business purposes. Since the stress-testing exercise is based on inferring rela-

Table 9.3 Data elements in the stress-testing framework

Historical data	Strategic policy variables	Time series of	Credit policy variables Product-design policy variables
	Macroeconomic performance	Time series of	Economic historical series by region
	Basis for panel structure of bank's internal performance	Time series of	Every loan originated in the historical period
		Cross-section of	Every loan originated in the historical period
Forecast data	Strategic policy variables	Time series of	Credit policy variables Product-design policy variables
	Macroeconomic performance	Time series of	Macroeconomic forecasts by scenario

tionships between portfolio performance metrics and the time-varying conditioning factors, ideally a long historical time series should be combined with the complete cross-section coverage of the portfolios.

Loan-level data elements validation checks

This essential panel structure – ie, the tracking performance dataset at the loan level – calls for dynamic checks and reconciliations with the general ledger and other accounting systems using loan-level data time series. Therefore, extra efforts are needed to obtain consistent time series in the historical data to serve as the basis of both dependent and independent variables in the econometrics of the quantitative engine. Large history recovery is hurdled with one-time past events such as acquisitions, or reconciliation of different source systems or acquisitions. It is highly recommended to take care of those aspects in the data preparation stage, rather than trying to model those impacts in the modelling specification.

Four particularly relevant checks have to be carried out to sign off on the loan-level panel data.

☐ The information needs to cover all the contracts that form part of the portfolio segments of interest and, when aggregated from the loan level to the portfolio level, tie out to the general ledger balances and historically call reports for delinquency, default and recovery information for all the different segments.

- ☐ The balance logic equation (Table 9.2) has to be observable in the data at the loan level, and any level of aggregation chosen as the unit to model in the quantitative engine.
- ☐ The ongoing update of the performance time series for existing loans, and the incorporation of new contracts, have to be able to form part of a replicable, monthly production process.
- ☐ All stakeholders must be participants in the model set-up design. Business lines, finance, treasury and risk experts together must agree on which data elements are considered relevant and of appropriate quality to adequately capture the evolving nature of the product mix in the portfolio.

This demanding effort should be regarded as an opportunity for data discovery. A formal data-discovery process results in a deeper understanding of hidden patterns and clusters that add high value in three key aspects of a robust stress-testing exercise. First, it is essential for the intelligent automation of a stress-testing monthly or quarterly production process. Second, data discovery informs the robust design of the quantitative engine, which estimates the relationships between the stress-testing conditioning factors and the performance of the loans in books. Third, it complements business insights and enriches the dialogue with supporting evidence. Examples of data-discovery tools that are considered best practice are non-supervised machine learning algorithms such as latent factor or cluster identification, principal component analysis and the systematic pre-processing analysis of outliers and missing values.

In addition to the history of loans cementing the cross-sectional and time series dimensions of the data structure, two general considerations are needed to get to the final data structure or performance dataset. The first concerns the length of the historical period it should cover; the other concerns the modelling level chosen. When the approach is heavily based on time series or panel data, econometrics recommends that the historical element goes back long enough to capture at least two changes in the business cycle. When this requisite is difficult to meet, it could be replaced by adopting other econometric designs built on very granular unit(s). This is somewhat related to the second consideration: what is the level of aggregation that better fits the needs of the framework? Although the starting level of observation is loan-level history, a

Table 9.4 A taxonomy for the segmentation of retail exposures in stress testing

		Segments									
		Geography	Lien	Product characteristics	Market segment	Origination segment	Credit risk indicators	Origination channel	Amortisation type	Loan type	Interest type
Retail products	Residential mortgages	State Metropolitan Statistical Area (MSA)	First lien Junior lien	Own/investment property Single family/multi-family Government-guaranteed	Refinance New purchase	Vintage	Credit score Loan-to-value ratio* Debt to Income	Branch On-line Targeted customer		Prime Alt-A Subprime Jumbo	Fixed Adjustable Option-adjustable
	HELOANs										
	HELOCs								Interest-only Ballooning Amortising		
	Auto loans			Commercial Private							New car Used car
	Credit cards			Corporate General purpose Charge card	Current and active Current and inactive						
	Student loans Overdraft loans Small business loans										

* When applies

decision has to be made to determine whether the model unit should stay at that level, be rolled up to more aggregated ones, or to combine different units of aggregation. The different needs of the stress-testing stakeholders must be set forth at the onset of the design and drive that decision. The correct econometric design should be specified accordingly.

Aggregation of loan-level data and modelling implications

The taxonomy presented in Table 9.4 is relevant for the aggregation defining the reporting and analytical capabilities at different layers of the bank's functions. Three alternative unit levels, ordered by increasing level of aggregation, are:

- ☐ loans;
- ☐ cohorts, frequently indexed by origination and called, in that case, vintages; and
- ☐ portfolio or some segment within a particular portfolio.

When modelling one of the three alternatives above, the conclusions do not downstream or upstream from one level to another. Interpreting associations at the portfolio/segment level as translatable to the loan level, or the other way round, will imply assumptions that cannot be carried out by the aggregation/disaggregation. Some stakeholders may have an interest in modelling one or another, or just going in-between, using vintages, but the reality is that a comprehensive approach that aims to reconcile different interests across the organisation needs to recognise the limitations of choosing one over another. Also, the alternative of constructing separate models for different model levels, although aiming for comprehensiveness, will fail to be integrated. Ideally, we want to consider all the three levels simultaneously, implying a multi-level modelling approach (see Table 9.5).

The essential merits of segmenting the rich granular data for retail exposures are presented in Figure 9.2, which is a stylised and purposely simplified way of illustrating the data alignment and model set-up using a panel of car loans. The figure is sequentially read row by row, from top to bottom. For three origination quarters in the history, granular loan data is gathered identifying credit risk policy variables at origination, such as FICO scores and LTV ratios

Table 9.5 Levels of aggregation for the panel data structure

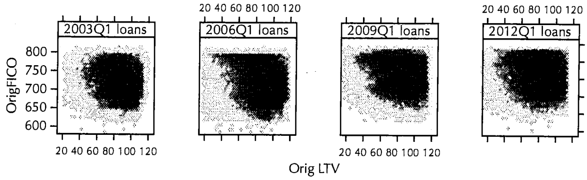
Observable factors of similarity	Credit characteristics		Product-life cycle characteristics	Economic conditions	Strategic efforts	Reduction in unexplained variability via:		
	Credit score	Underwriting standards						
Level 4 Geography	Very important for international or multiregional banks					Between policy-economic/market conditions		
Portfolio/ Level 3 segment					The policy variables are most frequently established at the portfolio/segment level.			Between policy-economic conditions
Cohort Level 2 (vintage)				The observed macroeconomic conditions makes loan-level units even more similar over time for each given type of credit, underwriting and product characteristic. The more variance among the credit groups at the loan level, the more explanatory power the macroeconomic conditions		Within origination similarity	Between credit/product-economic characteristics	
Level 1 Loan	The observed credit risk of a loan applicant entering the books in a given moment of time is likely to be more similar given the underwriting standards in place at that moment. That makes them more likely to receive products of similar characteristics.					Within credit similarity		

(first row). In addition, product-specific features must be considered; here, to simplify, we consider only high-level product features, such as interest rate and the loan contractual term (second row). However, in a real application, amortisation types and option-like features would also be included. In the example proposed, one can recognise an unsurprising pattern depending on origination date; the distributions of credit quality and revenue factors change over time, as macroeconomic factors evolve (third row).

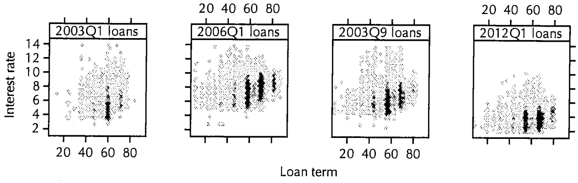
Following the sequence over time in Figure 9.2, from left to right, high LTV ratios seem to be capturing a shift in credit policy, favouring tighter standards. Analogously, interest rates for newer loans are increasingly lower, reflecting a low interest rate economic cycle. The bank seems to have reacted to this by accepting longer contractual terms, seeking additional revenue and accepting higher risk in return. The economic conditions pre-crisis increased the risk appetite and the high 2006 growth – captured by the extension and density of the scatter points in the first and second rows – sought to take advantage of a high interest rate environment, and credit standards lowered. The consequences of that combination of macroeconomic and bank's strategy is assessed by the last three rows in Figure 9.2. They depict performance in credit and prepayment risks, and maturity distributions for each of the four cohorts considered. Therefore, the figure successfully illustrates how the combination of loan data with the historical evolution of some key macroeconomic series for that portfolio captures how the risk appetite is shaped by economic conditions across the portfolio/segment of study. In this case, the bank clearly faced a trade-off between revenue and risk given market rates and the creditworthiness available in the economy at a given point in time.

The patterns observed in the data for products with larger contractual maturities and collateral based on real estate assets are expected to display different product-specific patterns in the data, attributable to the strategic appetite for some product features and the business cycle. Figure 9.3 depicts residential mortgage loans, again at different selected moments of origination. The interaction between the macroeconomic performance and the business strategy in this data is somewhat different to the one captured by the car loan data. Policy standards have been tightened, especially in the LTV ratios in the latest origination. Where the distribution of LTV ratios in the earlier

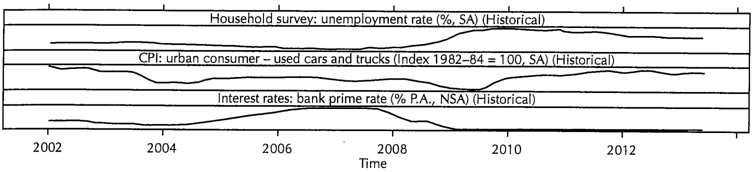
Figure 9.2 Car loan characteristics and performance tied to economic conditions



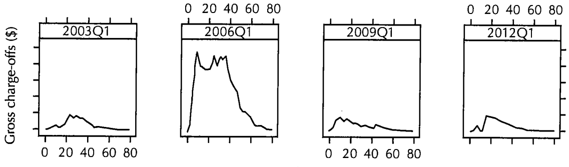
(i) Scatter plot of loan level data by FICO and LTV, originated four different quarters of the cycle



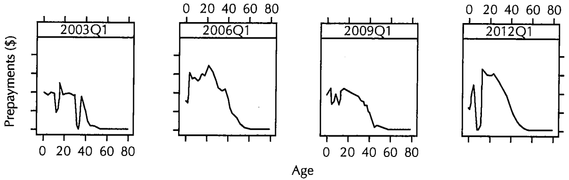
(ii) Scatter plot of the same loan level data above by term and interest



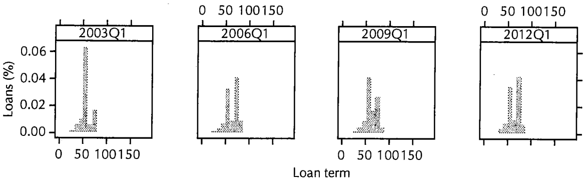
(iii) Key macroeconomic historical time series for the portfolio



(iv) Lifetime credit performance (gross charge-off dollars) for each of the four cohorts of loans originated in (i) and (ii)



(v) Lifetime prepayment dollars for each of the four cohorts of loans originated in (i) and (ii)



(vi) Distribution of loan terms for each of the four cohorts above

originations displayed two modes at 80% and 100% values, the most recent origination does not display such as stark bimodality any more. For the most recent origination, FICO scores are now predominantly higher than 700, and LTV ratios lower than 80%. There are still LTV ratios of 100%, but they are no longer the norm. The combination of a decline in the home price index and high unemployment is this time driving the tighter underwriting policy in a low interest rate environment.

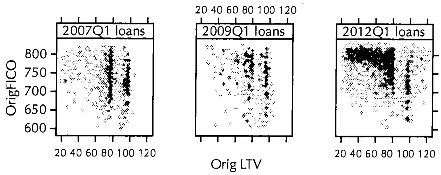
The point being made here is that these sensible insights, gained by studying repeated observations over time of multivariate origination factors, are quantifiable given the rich internal data available for retail exposures. Therefore, they could be captured by the appropriate design of the quantitative engine. This granularity gives flexibility to modellers to address the otherwise confounding nature of stress-testing conditioning factors when designing the econometric model.

Forecast data: scenarios and policy defining variables

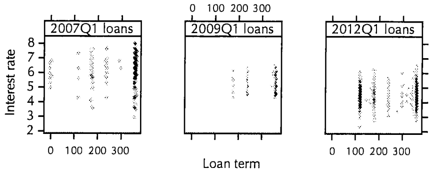
A handful of relevant macroeconomic stress factors for the selected metrics of interest already listed and overviewed in Table 9.1 are needed to capture the state of the economy. Some *a priori* business and product knowledge and well-established economic research would naturally be applied to subset relevant time series. Standard statistical methods can be then applied to select the actual definitive set of macroeconomic variables in the econometric design. However, this approach, which is the likely to become the most commonly applied in stress-testing exercises, faces two challenges.

First, the in-sample period only captures events that have been actually observed in the past. This is a limitation if stress testing is to be considered a pure forecasting exercise. However, what a sound implementation of stress testing can do is to quantify the impact of different factors – strategic, credit, product-specific and macroeconomic – which interplay and make risk manifest with different intensities and timings. This is not a pure retrospective analysis, but a way of identifying potential threads and opportunities in order to inform and control business and strategic actions. These will have long-lasting latent effects under different economic conditions, not necessarily catastrophic ones. That is, stress testing informs long-term, risk-aware active portfolio management. Admittedly, this is

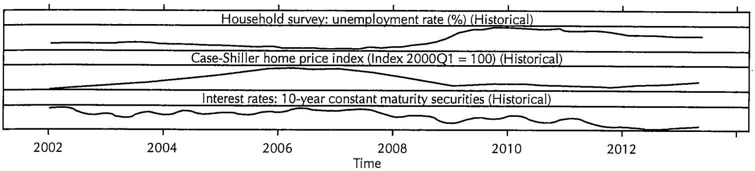
Figure 9.3 Mortgage loan characteristics and performance tied to economic conditions



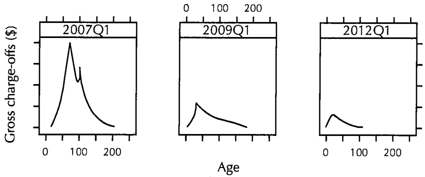
(i) Scatter plot of loan level data by FICO and LTV, originated four different quarters of the cycle



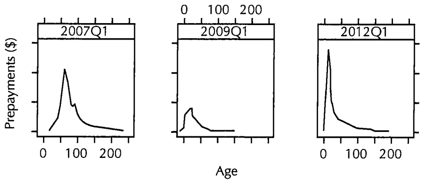
(ii) Scatter plot of the same loan level data above by term and interest



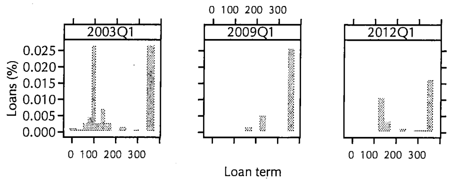
(iii) Key macroeconomic historical time series for the portfolio



(iv) Lifetime credit performance (gross charge-off dollars) for each of the four cohorts of loans originated in (i) and (ii)



(v) Lifetime prepayment dollars for each of the four cohorts of loans originated in (i) and (ii)



(vi) Distribution of loan terms for each of the four cohorts above

not a simple task, as the discussion on econometric design below points out.

Second, the forecasting period is still of a "what-if" nature. The forecast values for macroeconomic values are still determined exogenously, most likely in an economic scenario engine, using stochastic modelling and economic knowledge to obtain jointly realised values of many macroeconomic series. Those realised values are substituted in the econometric specification using in-sample estimates to forecast the future values of the metrics of interest. This calls for the strong assumption that a stationary equilibrium equation can be estimated.

A final challenge in setting up the forecast data concerns the integration of business strategic and credit and product-specific variables that are consistent with the economic forecasts obtained in the independent macroeconomic scenario generation engine. As illustrated by Figures 9.1 and 9.2, banks are likely to react to the economic conditions. Expert panels that bring together economic and business experts can help, but again this is still a subjective exercise. If one is willing to dismiss feedback effects and consider the macroeconomic variables as purely exogenous conditioning factors to which the bank's business strategy reacts, then the econometric design can quantify those linkages with macroeconomic series.

ECONOMETRICS OF RETAIL STRESS TESTING

This section will illustrate the multiple choices available to align the panel data structure described above with the segmentation and aggregation determined by the framework design.

Univariate and multivariate data

The left-hand side of the regression equation can either be a single time series vector or a number of vectors for several metrics whose evolutions are interdependent. Some formal notation can help at this point. In the simple (or univariate) approach, left-hand side variable y is a vector of dimension Tx1. There will be as many independent econometric equations as metrics of interests. As an example, the modeller will estimate, independently, prepayment rates and charge-off rates for econometric equations over a given historical period.

Alternatively, the modeller could have theoretical or domain knowledge to consider that some metrics should be estimated together. In this case, the left-hand side is a matrix Y of dimension MxT, where M is the number of metrics modelled in one single equation. This multivariate approach is more challenging than the more common multiple, single-equation models estimated independently. However, it is frequently used in vector autoregressive settings in time series applications for aggregate time series. Following the previous example, the modeller will specify a left-hand side variable $Y = [y_1\ y_2]$, where the Tx1 vectors y_1 and y_2 will be charge-off rates and prepayment rates, respectively. There are other alternatives to multivariate regression to simultaneously model several metrics at the same time. A possibility is to estimate seemingly unrelated regression equations (SURE), where the covariates may be different from equation to equation, giving more flexibility to the modelling than multivariate regression. The generalised method of moments (GMM) extends SURE to non-linear equations, if that were to be considered more suitable. Table 9.6 summarises these designs depending on the type of data (univariate, multivariate) in the left-hand side of the econometric design, and the data structure (time series) panel. The (general) panel data structure with which the framework design starts allows for aggregation at different unit levels of interest. Either an aggregated time series for one single segment – eg, a portfolio or sub-portfolio – can also be formed, or cross-sectional and longitudinal datasets can be formed.

Time-series, cross-sectional and longitudinal designs

When aggregated data are enough to fulfill the informational requirements set by the stress-testing stakeholders, autoregressive

Table 9.6 Econometric designs by data structure

Type of data	Data structures	
	Time series	**Cross-sectional/panel data**
Univariate data	ARIMAX	Several independent equations with a single vector as dependent variable
Multivariate data	VARMAX	Multivariate regression
		SURE-GMM
		Conditional single-equations + joint distribution of error terms
		Marginal distributions + copulas

and vector autoregressive regressions with exogenous covariates can be very versatile. Vector autoregressive moving-average processes with exogenous regressors (VARMAX) are designed to model the dynamics of a multivariate left-hand side using as predictors their past values, and past and contemporaneous economic or policy variables. In other words, when one is interested in modelling the dynamics among, say, outstanding balances, prepayments and charge-offs, and their explanatory variables at the portfolio level, a VARMAX might be an ideal setting. Therefore, this is a very rich framework when one is more interested in capturing timing and the dynamics over relationships among sub-segments and different levels of aggregations. Also, the VARMAX setting offers well-established econometric tools to deal with structural change and non-stationarity of time series data, which are of clear value in macroeconomic-driven stress testing, particularly when a long history of data is available.

In case historical data are not long enough or the analysis is required at a more disaggregated level than the portfolio level, such as cohorts, sub-segments or various clusters of borrowers, loan-level panel data can be used. Such a panel data approach could capture within and between effects among groups of borrowers, market segments and product features. There are many regression techniques available for time series, and even more so for cross-sectional and longitudinal data. However, a discussion about them is beyond the scope of this chapter. In either case, the econometric design should display as much as possible these desirable properties:

☐ simple;
☐ helpful in avoiding confounding effects;
☐ able to capture non-linear relationships;
☐ able to capture various linked macro shocks; and
☐ able to capture macroeconomic and product behaviours beyond what occurred in the past.

Measurements of dependent variable metrics

Another aspect affecting the econometric design, and in particular the model selection, is the units of the metric to be estimated. In retail stress testing, the types of metrics are:

- dollar amounts (eg, balances and their components, such as prepayment and repayment, delinquency bucket balances, default dollars, charged-off dollars, recovery dollars);
- fractions or rates (eg, charge-off rate, prepayment and repayment rates, delinquency rates);
- integer or count data (eg, number of defaults, number of times in delinquency states);
- binary outcomes (eg, prepaid versus non-prepaid, defaulted versus non-default); and
- a combination of discrete outcomes with time-to-event data (eg, time to default, time to prepay, time to obtain complete recovery).

Table 9.7 displays a menu of specifications for usual measurement units used for various retail stress-testing metrics. For the three first types, the standard approach is to use the generalised linear models (GLMs) approach. The dependent variable is considered a random variable belonging to the exponential family and other non-exponential distributions and multivariate distributions (such as multinomial), or even to not-fully-specified distributions (such as the power family). The mean of y is transformed via a link function that can be modelled as a linear combination of covariates and parameters, ie, the linear predictor portion. Unlike standard regression, where distribution assumptions are not strictly needed, the GLM is more parametric in the sense that it imposes a distribution for y, which is shaped by the variance function. This function relates the variability of y to the fitted mean of the dependent variable. Rather than applying transformations to dependent variables that do not fit linear regression assumptions, GLM models produce forecasts in the original level of y rather than in its transform, thereby avoiding biases and difficulty in interpretation. The stress-testing capabilities are therefore enhanced by incorporating the GLM framework. Table 9.7 also shows that retail stress testing can be designed to link stress-testing conditioning factors to cashflows, and also to probabilities and rates during the life cycle of the product.

Stress-testing conditioning covariates

The set of conditioning factors, represented by X, is a matrix including macroeconomic (X_M), credit risk, product life-cycle (X_P) and strategic conditioning variables (X_S). Formally, $X = [X_M\ X_P\ X_S]$.

Table 9.7 Types of performance metrics and suitable econometric frameworks

LEFT-HAND SIDE METRIC TYPES AND ECONOMETRIC MODELS OPTIONS

Type of metric measurement		Econometric framework	Family of models	Link function	Variance function	Application examples
Continuous	(-∞,∞)	GLM (includes linear regression)	Gaussian	Identity	Constant	Levels
	(0,∞)			Log	Constant	
	[0,∞)		Gamma	Inverse/canonical	Quadratic	Rate per unit of the model response
	[0,∞)			Log	Quadratic	Log-rate of the model response
	[0,∞)			Identity	Quadratic	Duration data
	[0,∞)		Inverse Gaussian	Identity	Cubic	Duration data
	[0,∞)			Log		Duration data
	[0,∞)			Inverse/canonical	Cubic	High initial peak, rapid drop and long right tail
	(-∞,∞)		Power		Quadratic	
Fractional	[0,1]		"Flogit"/binomial	Logit/probit		Fractions or rates that can be be zero-valued
Discrete	Binary		Binomial	Logit/probit		Similar proportion of zeros and ones
				Complementary log-log		Uneven proportion of zeros and ones (rare outcomes)
	Count		Poisson	Log	Constant	Count, duration and rate data
			Negative binomial	Log	ML quadratic	Count, duration and rate data
	Multiple		Multinomial	Logit/probit		
	Ordinal		Ordered	Logit/probit		
				Complementary log-log		
			Continuation-ratio	Logit/probit		Transition-ordered categories
				Complementary log-log		Transition-ordered categories
			Family of models	**Distributions**		
Discrete/ continuous	Time to event	Survival	Cox proportional			
			Accelerated failure times	Exponenial		
				Weibull		
				Lognormal		
				Loglogistic		
				Gamma		
			Hazard models	Exponenial		
				Weibull		
				Gompertz		
	Time to events		Competing risk models			

For sake of generality, we do not specify a separate matrix for credit characteristics; these can be either explicitly included as quantitative or categorical variables in X_S, or can be used to form strata or clusters, not necessarily captured by indicator variables. This comment extends to any set of variables related to distribution by segments (eg, regional, marketing channels).

The selection of the covariates in X is challenging given the nature of the stress-testing exercise

- ☐ Economic theory, which should guide any selection over pure statistical fit performance, might be inconclusive or at odds with empirical observation, or with business experience. A challenge in the framework is to reconcile all. Variables that enable interactive capabilities between the quantitative engine and users should be selected, even at the expense of traditional statistical selection criteria.
- ☐ The more segmented or granular the aggregation used in the model, the richer the composition of X_M must be. For instance, segmentation by geography calls for regional macroeconomic series as opposed to national levels.
- ☐ Assuming one-time historical relationships hold in the future under all scenarios can trigger the risk of over-fitting, turning temporary relationships into long-term trends. This also makes a case for using granular level data, moving away from the aim of finding a stable relationship between the bank's aggregate portfolio performance and the macroeconomic variables.
- ☐ Life-cycle characteristics are traditionally modelled using *ad hoc* splines that fit a cohort evolution. However, those splines should be adaptative in nature. Besides age, contractual characteristics of loans and the market variables should explicitly interact with life-cycle trajectories. In other words, splines should be modelled using relevant elements of X_P and X_M.

The last remark might explain why there is focus on a single specific aspect of the taxonomy. The vintage origination approach has become one of the most popular alternatives in the econometric design of stress testing. There are, however, other alternatives, in which the econometric design is more agnostic to begin with regarding the linkage between origination segments and performance of the portfolio. In particular, cluster, hedonic and multi-level designs are more data-intensive ways of approaching the relationship between credit and product characteristics and future performance given the macroeconomic conditions. Consumer portfolio stress testing offers the required richness in terms of data to adopt these different approaches.

Figures 9.1 and 9.2 suggest that the defaults of loans are related to the economic conditions observed at inception. In other words, we can consider that the loans that had a particular combination of FICOs, LTV, term and coupon react in a specific way to the evolution of the economy. This implies that the same FICO score for loans in 2006 and 2009 may not be directly comparable. Vintage modelling dismisses heterogeneity among pooled loans, but that might preclude the observation of different relationships across scenarios, as well as oversimplifying the relationship between the elements of X and y, either by incorporating confounding factors or assuming a stable relation over time and across scenarios.

At the same time, some elements in X, particularly in X_M and X_S, not necessarily relevant to explain loan or cohort performance, might affect the overall portfolio dynamics. Those are common factors shared by clusters or cohorts of loans, and help in determining the evolution of the large mass of balances in run-off. This multi-level approach is able to encompass richer dynamics across the modelled units.

Table 9.8 summarises how to approach layered econometric designs in retail stress testing. The observable covariates can be combined with different types of effects, random or fixed, to capture within- and between-variance effects. The effects can be made explicitly conditional on the elements in X, helping to avoid confounding relationships. This combination of covariates and effects at different levels of aggregation renders a hierarchical structure that can be of great use in retail stress testing.

Most of the single-level designs are compromises between a particular aggregation level choice and the taxonomy that the framework specifies. While working at the loan level captures the higher level of cross-sectional variability (across borrowers), that richness can be an obstacle in traditional econometrics settings to establish a quantifiable link with macroeconomic factors. Time series on the other side of the spectrum allow the modeller to capture inertias in the run-off balances of the portfolio, but offer little guidance in terms of newly originated loans. Vintage modelling offers the possibility of modelling the performance and the product life-cycle aspects of the metrics. However, it is not granular enough to take into account that

Table 9.8 Econometric designs by aggregation and multi-level units in retail portfolios

				Right-hand side			
		Modelled unit	**Econometric design**	**Covariates**	**Observable characteristic captured**	**Effects**	**Variance/heterogeneity captured**
Level of aggregation	Higher	Portfolio/segment	Time series	X_M			
				X_P	Only at the portfolio/segment level		
				X_S	Only at the portfolio/segment level		
		Cohorts/vintage	Panel data	X_M		Fixed Random	
				X_P	Product life-cycle splines		Age-period-vintage effects
				X_S	Only at the origination level		Wiithin origination similarity
		Strata/clusters	Hedonic/latent factor	X_M, X_P, X_S	All covariates help to identify the unobservable quality over time		Between credit/product/economic similarity
		Loans		X_S			Within credit/product similarity
	Lower			X_P			
		Multi-level approach	**Econometric design**				
Degree of granularity	Higher	Portfolio	Nested/ hierarchical	X_M, X_P, X_S	Covariates are assigned by relevance as conditioning factors at different levels of the hierarchy	Fixed Random	All of the above
		Clusters/strata					
		Loans					
	Lower	Cohorts/vintage	Panel data	As above			As above

different distributions of X_P and X_S at different points in time may reveal a different profile of risk in the portfolio, given X_M. Regression with clusters or strata, especially when combined with latent factors or hedonic estimation, is a good option for modelling the quality of the portfolio over time, exploiting the different combination of X_M, X_P, X_S at the right level of aggregation. Finally, multi-level modelling establishes a hierarchy of different units, and can be considered the most explicit approach to avoid the compromises of using a single unit of aggregation. Also, multi-level modelling is a broader family of designs in the sense that it can be viewed as encompassing other approaches, such as vintage modelling.

A FRAMEWORK USE CASE

As a summary of the discussion so far, a use case is outlined.

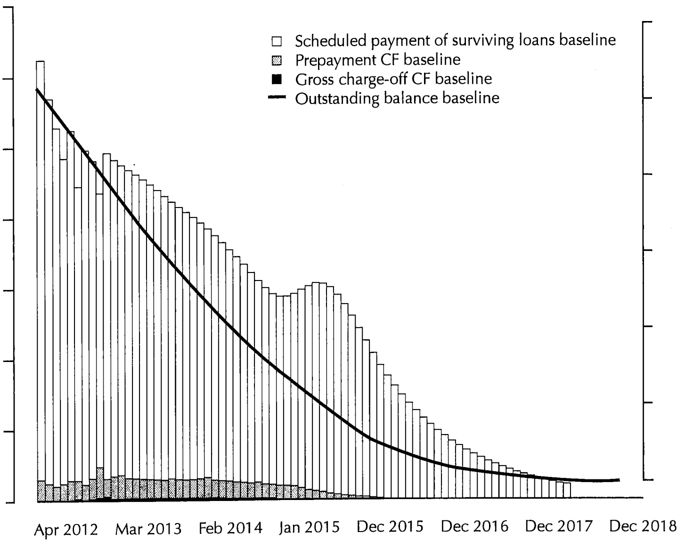
- ☐ Define the scope of the framework in three dimensions:
  - ○ metrics of interest (Table 9.1);
  - ○ taxonomy or segmentation (Table 9.4); and
  - ○ stress-testing explanatory variables.
- ☐ Align the internal data, making sure that:
  - ○ cashflow components are consistent with a balance equation holding over time and segments (Table 9.2);
  - ○ the aggregation applied in the data is well suited to the degree(s) of granularity that are of interest across the enterprise (Table 9.5); and
  - ○ a rich panel structure tracking long historical performance of all loans in the segment, with product-specific characteristics that is ready to be aggregated at the desired level(s).
- ☐ Define the ("what-if") stress scenarios combining macroeconomic drivers with the strategic ones for different layers and segments.
- ☐ Apply an econometric design for the chosen data layout and the consistency of cashflows in projections across scenarios. Consistent cashflows are attained either using econometric designs applicable to multivariate data, and/or making sure that cashflows drivers are jointly modelled, eg, defaults and prepayment as competing factors (Tables 9.6 and 9.7).
- ☐ Assess the portfolio risks and strategy by projecting the performance of:

- loans by segment already in books, under different scenarios (Figures 9.2, 9.3 and 4);
- future originations by segments, under different business and macroeconomic scenarios; and
- the entire portfolio segmenting accordingly (Figure 9.5).

Figure 9.5 provides the resulting risk/return roadmap of the retail stress-testing framework. It illustrates in a stylised way the resulting output of applying the framework to the portfolios of loans such as the ones in Figure 9.3. There, loan-level data from existing residential mortgage loans in a hypothetical book was gathered and organised following an intentionally simplified taxonomy based on FICO scores, LTV ratios, loan terms and interest rates. The first six matrices, in chronological order, project the gross charge-offs for each cell of FICO and LTV. The annual charge-offs rates are given in numbers, and the intensity of the grey scale applied at each cell represents the share of the balance of the portfolio in that particular bucket. A particular macroeconomic and business strategy has been assumed for future performance and new originations. In particular, a strict credit policy was assumed with conservative growth due to the weak real estate market. The revenue piece is reproduced in parallel. Although the interest rate scenario simulated assumes in the medium-term increasing interest rates, the restricted future growth is not enough to mitigate the previous low interest rate condition. For the sake of simplicity, Figures 9.4 and 9.5 focus only on the revenue and credit losses aspects, but the projections, say for risk-weighted assets (RWAs), will be obtained from the same framework in a similar manner.

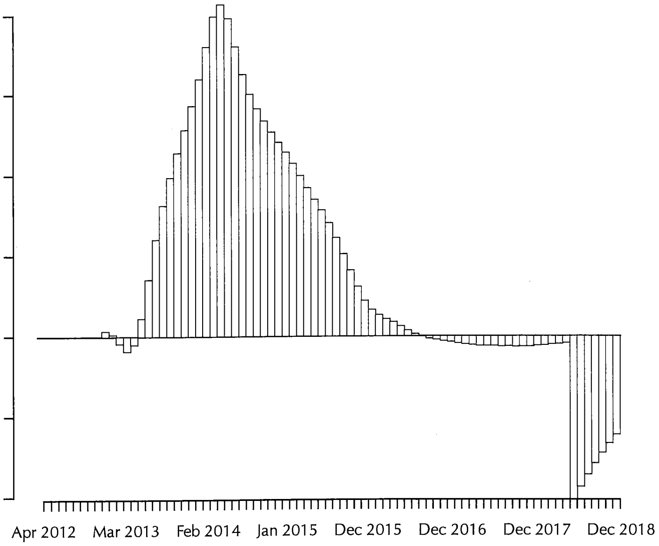
As described above, the model design, data segmentation and metrics forecasted should also be done with the business applications in mind. A comprehensive, integrated loss forecasting and stress-testing framework could be used to monitor the portfolio risk and model business activity, and serve as a what-if analysis tool for various strategic considerations and help establish a risk appetite functionality that is tied to portfolio and capital management. An integrated stress-testing framework serves this purpose by modelling rich loan-level data at the right level of aggregation so that it is able to quantitatively capture opportunities of revenue and warn against the losses in the portfolio.

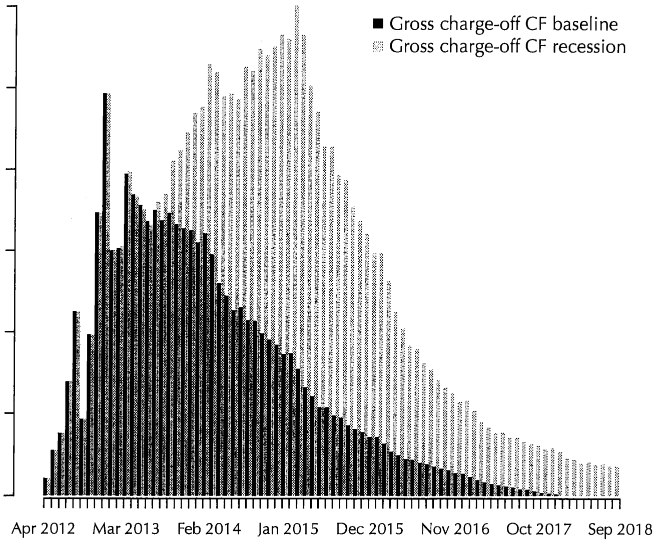
Figure 9.4 Consistency of cashflows (CFs) across scenarios



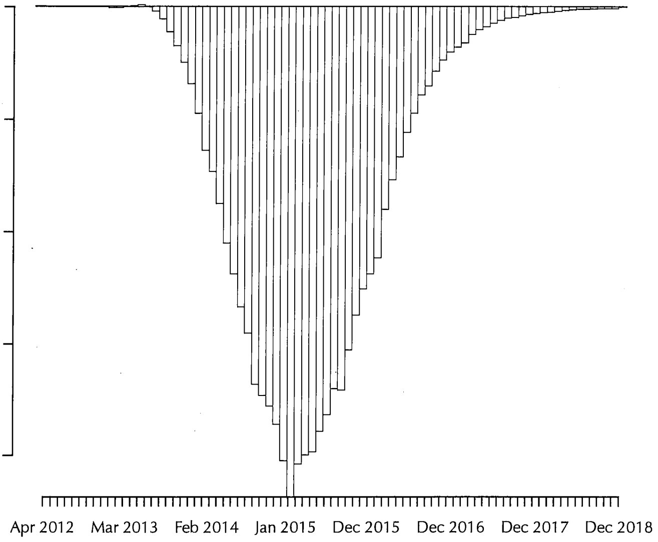
Baseline scenario: CFs projedctions for a vintage of amortizing loans

Differences in scheduled repayment CFs (baseline-recession)



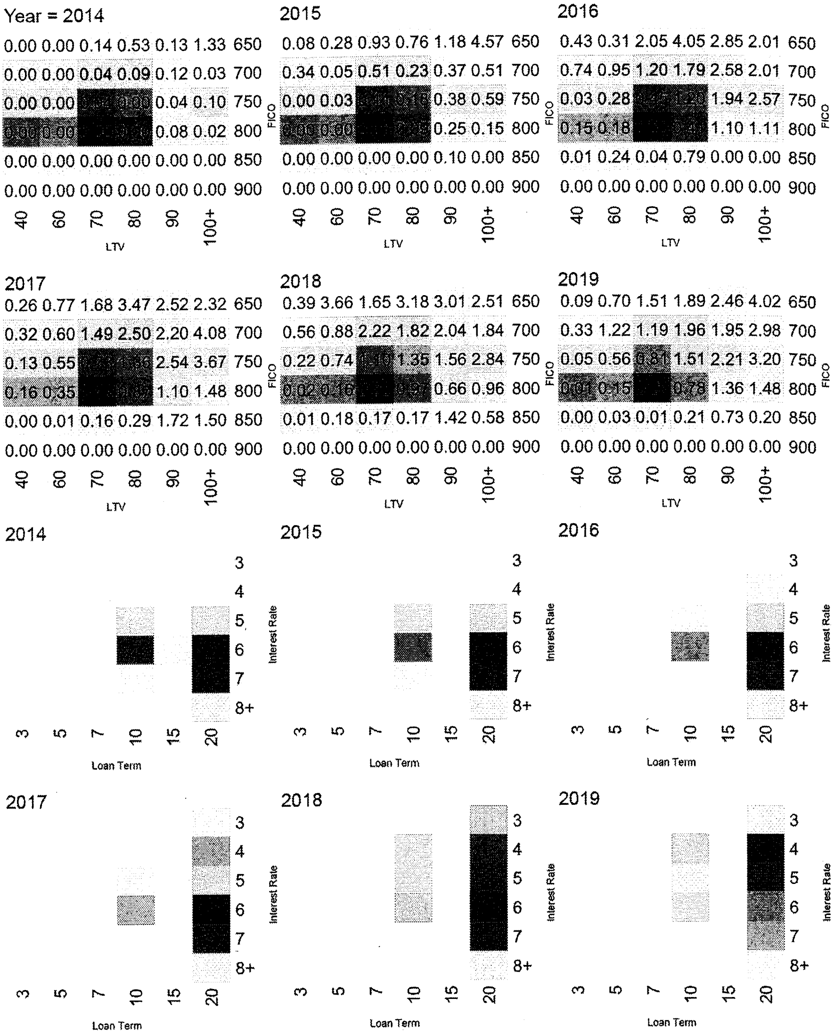


Gross charge-off CFs (baseline-recession)



Differences in prepayment CFs (baseline-recession)

Figure 9.5 Projection of portfolio projections: credit losses and interest revenues



CONCLUSION

CCAR, and stress testing in general, offer an opportunity to revamp the analytics of consumer portfolios in a manner that serves multiple purposes across the bank. As illustrated, a consumer stress-testing platform should provide various metrics by which the business and risk professionals could set the risk appetite and monitor the performance over time.

The key aspect of stress testing for consumer portfolios is broader than the activities around quantification and the number of metrics produced. Establishing a robust stress-testing framework is not only about having the best predictive models, it should involve a thorough discussion about the risks in the portfolio and forming a joint awareness about how the future economic conditions could adversely impact the portfolio performance and the bank's ability to withstand adverse stress conditions.

Not every business action can be modelled, and for that reason stress testing should not be perceived as an all-modelling exercise. However, the comprehensive nature of the CCAR exercise should inform the model design as well as the way risk intelligence is formed and executed across the enterprise. On one side of the fence, quantitative developers have to bring into their models the complexities and risk drivers of the product as dictated by business leaders. On the other side, business and finance partners need to challenge the models, understand models' shortcomings and omissions, and ultimately complement them with their vision on business strategy. In this way, business partners actively provide qualitative support and arguments to complete the quantification side of stress testing. Risk, treasury and business lines working in a collaborative and coordinated fashion is not only a best practice, but also a way of approaching active portfolio management using all the business intelligence resources available in the bank.

10

Market and Counterparty Risk Stress Test

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The largest US banks substantially enhanced their stress-testing capabilities in the aftermath of the financial crisis of 2007–08. This effort has been motivated by both internal and external demands for more comprehensive risk measurement and capital assessment frameworks.

The Federal Reserve Board (FRB) has implemented its Comprehensive Capital Analysis and Review (CCAR) programme[1] for the largest banking holding companies (BHCs), those with total assets greater than US$50 billion. The annual CCAR process has taken place since 2011, following in the footsteps and success of the initial Supervisory Capital Assessment Program (SCAP) conducted in 2009. The SCAP, and the public release of its results in May 2009, is recognised as a crucial turning point in the financial crisis in the US, as it increased transparency of the risks faced by the largest US banks and confidence in the capital sufficiency of the banks to withstand further deterioration in the economic and market conditions at the time.

In 2010, the Dodd–Frank Wall Street Reform and Consumer Protection Act (DFA) institutionalised the stress-test regime.[2] The DFA charges the Federal Reserve with regulating and conducting the stress tests of so-called covered companies – ie, large BHCs and other systemically important non-bank financial institutions as designated by the Financial Stability Oversight Council (FSOC).

The DFA established that covered companies should conduct two stress tests each year. In the mid-year test, which was conducted for the first time in 2013, each company should develop its own company-specific baseline, adverse and severely adverse scenarios to reflect its individual operations and risks. In the annual test, the BHCs should use supervisory scenarios developed by the Federal Reserve. The Federal Reserve should also calculate its own stress test of each company based on the risk exposure data provided by the company and the Federal Reserve's own supervisory scenarios. The results of the DFA stress tests (DFAST) have been closely examined by market participants, analysts, rating agencies and other parties interested in assessing the capital adequacy and business prospectuses of US financial institutions.

This chapter will discuss the implementation of a stress-test programme and the design of the stress-test scenarios for market and counterparty credit risks. In particular, we will discuss the integration and coherence of the macroeconomic, market and counterparty risk stress scenarios. We recommend certain features to enhance the stress test of market and counterparty risks: the explicit consideration of the hedging and liquidity dynamics of trading portfolios, reverse stress testing for identification of portfolio-specific market risk vulnerabilities and the simulation of dynamic hedging costs of credit valuation adjustments (CVAs).

The chapter is organised as follows: the first section explores the specification of the macroeconomic scenario and its role in providing structure and coherence to the stress-test exercise. The second section discusses fundamental characteristics of the market and counterparty risks, and how the stress tests of those risks can be designed and linked to the macroeconomic scenario. The following section looks at the specific risk characteristics and vulnerabilities of the business models of commercial and investment banks, and the stress tests that are most appropriate for them. We finish by presenting some concluding remarks and recommendations.

THE MACROECONOMIC SCENARIO

It is useful to have a macroeconomic scenario to guide the stress-test programme, and to provide structure and coherence to the various specific stress tests of the different types of risks and businesses of the financial institution. From the regulators' macroprudential perspective, a guiding macroeconomic scenario that is applied to all banks, aligns the specific stress tests performed by each bank, and allows the regulator to develop a comprehensive perspective of system-wide risks.

The typical macroeconomic stress scenario portrays a recessionary economic environment characterised by declines in gross domestic product and employment, as well as declines in equity prices, credit quality and house prices. The severity of the supervisory scenario used in SCAP and CCAR has varied across their implementations: it was roughly equivalent to a moderate 1-in-10-year recession in the SCAP 2009 and CCAR 2011, and it was a more severe 1-in-50-year recession in the CCARs of 2012 and 2013. The changing severity of the scenario has reflected the evolution of the downside risks of the gradually recovering US economy.

In its Regulation YY,[3] the FRB defined its expectations about the severity of the three supervisory and company-specific macroeconomic scenarios to be used in DFAST.

- ☐ The baseline scenario is defined as a set of conditions that affect the US economy or the financial condition of a covered company, and that reflect the consensus views of the economic and financial outlook. It should echo the views of the macroeconomic outlook expressed by professional forecasters, government agencies and other public sector organisations as of the beginning of the annual stress-test cycle.
- ☐ The adverse scenario is defined as a set of conditions that affect the US economy or the financial condition of a covered company that are more adverse than those associated with the baseline scenario, and which may include trading or other additional risk components. The adverse scenario will, at a minimum, include the paths of economic variables that are generally consistent with mild-to-moderate recessions.
- ☐ The severely adverse scenario is defined as a set of conditions that affect the US economy or the financial condition of a covered company that overall are more severe than those associated with the adverse scenario, and which may include trading or other additional components. The severely adverse scenario will, at a minimum, include the paths of economic variables that are generally consistent with the paths observed during severe, post-war US recessions.

In November each year, the FRB specifies the supervisory scenario to be used for the annual stress test of BHCs' profit and losses over the nine calendar quarters following September 30. The results of those stress tests are publicly reported by the FRB and by the BHCs in March. At mid-year, each BHC specifies its own company-specific macroeconomic and market scenarios to be used to project its profit and losses over the nine calendar quarters following March 31. The results of those calculations are publicly reported by BHCs in September.

The FRB and the BHCs have developed various econometric models to link the BHCs' stressed revenues and losses to the variables defining the macroeconomic scenario. The macroeconomic scenario is specified via the trajectories of the key economic and market variables over the nine quarters comprising the CCAR's capital planning period. The FRB's macroeconomic scenario has typically displayed a V-shape, with the economy initially contracting and then recovering towards the end of the nine-quarter capital planning period. The V-shape is important because it determines that the most pressing time for the banks' capital adequacy ratios may be an intermediate point within the capital planning period, when the capital ratios reach their minimum levels prior to the healing effects of the ensuing economic recovery.

STRESS TEST OF MARKET AND COUNTERPARTY RISKS

With the macroeconomic scenario painted on the background, the design of the specific stress tests of market and counterparty risks presents challenges and opportunities for banks. Below we discuss the design of the specific stress tests for those risks.

Stress test of market risk

Market-risk stresses present various challenges for their alignment with a guiding macroeconomic scenario. This is because of the intrinsic characteristics of banks' trading activities and risks.

Only innovations (news) cause market prices to change

Market price changes tend to occur ahead of the time when the related economic events occur. They respond to changes in market participants' expectations and required risk premia, and transcend the information contained in contemporaneous economic events.

This means that price changes occur asynchronously to the surrounding economic environment. To illustrate this point, suppose that current market prices incorporate a 90% probability of an upcoming recession and large risk premia due to the perceived macroeconomic uncertainty. When the recession eventually materialises and its severity becomes clearer, it is possible that equity prices stay at the current level or even go up if the recession turns out to be less severe, causes less economic damage and/or has shorter duration than initially was priced in the market. The implication of this for stress-test design is that there may be multiple market scenarios that could be consistent with a contemporaneous recessionary environment, each one of the market scenarios corresponding to what the stress-test designer determines to be already incorporated in the pre-recession market prices.

Below is a news clip that illustrates the asynchronous developments in the economy and in market prices:

> "May 13, 2013 (Bloomberg) – Euro-area data this week will probably reveal economic scars of the sovereign debt crisis confirming that the region is now suffering the longest recession since the single currency's creation. Gross domestic product in the 17-nation economy fell 0.1% in the first three months of 2013, a sixth straight quarterly decline, according to the median of 39 economists' forecasts in a *Bloomberg News* survey. That would exceed the 15-month long contraction in 2008–09 during the financial crisis. The euro area's jobless rate rose to a record 12.1% in March, with 19.2 million people out of work and youth unemployment at 24%. In France, the number of people actively looking for work reached a record 3.225 million. [Yesterday] European stocks declined from their highest level in almost five years before a report that may show US retail sales fell in April for a second month. The Stoxx Europe 600 index slid 0.2% to 304.29."[4]

This clip illustrates the simultaneous occurrence of a depressed economic environment and a very high level of equity prices. This divergence can possibly be explained by various factors, including that markets may already be pricing a future recovery, or the market risk premium has decreased because economic downside risks had declined or the liquidity premium has declined because of expansionary monetary policies.

Net of the hedges, only secondary risks remain

A full market scenario to stress test a large and complex trading portfolio requires the specification of stress shocks to thousands of market risk factors. This is because banks tend to actively hedge their market risks and eliminate most of the primary, directional market-risk components. The active hedging of trading portfolios is the consequence of traders being constrained, in multiple risk directions, by extensive risk-limiting structures. The residual (net of hedges) risk components tend to be secondary, more subtle types of risk and related to the imperfections of the hedging strategies across different types of products, maturities, credit qualities, delivery locations, etc. Directional stress shocks (eg, equities down or bonds down) targeted at the primary risk components can miss or even obfuscate the residual, secondary risks. Systematic and comprehensive reverse stress-test frameworks tend to be more effective to identify residual risks and specific vulnerabilities of banks' trading portfolios.

The concept of a reverse stress-test framework is consistent with the CCAR's instructions and guidance:

> "A BHC's stress scenario should describe a severely adverse hypothetical combination of circumstances designed with the BHC's particular vulnerabilities in mind. Specifically, [...] the BHC stress scenario should be designed to stress factors that affect all of its material exposures and activities, capturing potential exposures from both on-and off-balance sheet positions."[5]

The CCAR instructions urge banks to focus on risks that are specific of each BHC and its portfolios. Thus, the stress scenarios, especially the ones applied to assess market risk, should consider the configuration of the BHC's current trading portfolio.

Dynamic hedging reduces the impact of non-linearities

Banks tend to dynamically delta hedge their liquid non-linear risks (eg, as contained in options and other option-like products). This presents challenges for stress-test design – for example, if the bank is typically long convexity as part of its market-making strategy, it will show large gains when the non-linear positions are stressed with large price shocks. However, in reality, those gains will never materialise because the bank will continuously rebalance the delta hedge of the liquid non-linear risks. Thus, large shocks applied to liquid, non-linear risks will produce a fictitious positive outcome that bears no connection to the reality of the results of its trading strategy. However, if the non-linear risks were illiquid, then large shocks would be proper since the bank would not be able to dynamically adjust the hedges of those illiquid risks.

Liquid risks move fast

Positions in liquid risks tend to change quickly because of active trading. Thus, an instantaneous and static snapshot of the bank's trading portfolio may not represent its features over a long time horizon. This is especially important to consider at investment banks that routinely underwrite and distribute large blocks of equities and fixed income securities. Applying large stress shocks to liquid and movable risks does not portray correctly the reality of the potential stress losses those market moves may inflict on the bank.

Considering the above, the question is: how should a bank design the stress test of its trading portfolio so that it is consistent with a given macroeconomic scenario? There are a few different ways to achieve this. In all of them, the specification of the market shocks will exploit some flexibility with respect to the guiding macroeconomic scenario, but it will be coherent with it in terms of statistical severity and overall direction.

A recessionary macroeconomic scenario suggests certain overall directions for the market price shocks. For example, equities prices should fall, credit spreads should widen, interest rates should generally fall, strong currencies should appreciate and commodities prices should generally fall. Those general trends leave room for further specifications related to shapes of the interest rate and other price/rate curves, level and shape volatility surfaces, idiosyncratic risks, etc.

Typically, thousands of market risk factor shocks need to be specified to completely characterise a market scenario. The large number of shocks offers opportunities for banks to exercise discretion in their stress tests and to explore important specificities and vulnerabilities of their trading activities and portfolios. The impact of market price changes should be examined in multiple directions, and at least in the two main directions, up and down, to capture long and/or short exposures in each risk class. Interest curves and implied volatility surfaces may be subject to other, more complex, shock patterns. Probabilistic approaches, which are similar to the usual value-at-risk

(VaR) models, can be useful to generate systematically a large number of market scenarios. Of course, the risk horizons that determine the size of the market shocks, and the statistical confidence level that is used to characterise the stress level, need to be chosen to meet the required severity of the stress test. For example, risk horizons of one or two years and statistical confidence levels above 99% are typical.[6]

A key design feature to consider is the market liquidity of the various market risks. All else being equal, liquid risks should command smaller stress shocks than illiquid risks. This can be illustrated by considering a position on an investment-grade corporate bond. Most of the price risk of the corporate bond can be explained by changes in the level and shape of a general interest-rate curve (eg, the US Treasury or swap curve). The general, reference interest-rate curve tends to be a very liquid risk. However, the corporate bond price changes are also determined by the changes in the credit spread curve of the issuer of the bond. Changes in that credit spread curve can be partly attributed to general, market-wide changes in credit spreads and partly to idiosyncratic changes of the issuer-specific credit spread. General changes to credit spreads can be hedged with credit indexes (eg, CDX or iTraxx) that are more liquid than single-name credit default swap (CDS) hedges for a specific issuer. Thus, the corporate bond position contains three different risk types and liquidities: i) general interest-rate risk that is very liquid; ii) general credit spread risk that is somewhat liquid; and iii) issuer-specific credit spread risk that is somewhat illiquid.

The decomposition of the corporate bond risks described above represents the reality of how traders assess and manage their trading risks. The trader hedges the various different risks contained in the corporate bond – ie, the sensitivities of the price of the bond to the different market risk factors. The trader aggregates the risk sensitivities to each risk type across their entire book of trades and then they hedge the net risks. The risk limits on their activity are also set on the net risks by type of risk. Typically, the corporate bond traders will hedge their net general interest-rate risk exposure with US Treasuries or interest-rate swaps, their net general (portfolio-wide) credit risk exposure with CDX or iTraxx and their net name-specific risks with name-specific CDSs or short bond positions.

A stress-test framework that purports to represent the actual hedging dynamics of the banks' trading activities needs to apply different shock sizes to those three types of risks, consistently, across the entire trading portfolio. The different shock sizes purport to capture the real economic feature that liquid risks are hedged more actively than illiquid risks, and their contributions to stressed trading losses are smaller than the ones of illiquid risks. The large trading losses that occurred in 2008 were caused by illiquid risks in the banks' trading books, risks that were mainly contained in structured credit products (securitisations).

Stress testing of counterparty credit risk

Banks that are involved in trading activities usually have exposure to derivatives counterparty credit risk. This risk manifests itself via the mark-to-market of the CVA,[7] and via counterparty default losses. Both components need to be stress-tested. CVA and its inherent risks are a complex risk management topic. There are many intervening risk factors in CVA: the prices and rates that drive the value of the derivatives traded between the two counterparties; the credit spread curve of the counterparties; the co-dependencies (correlations) of all those risk factors; and dynamic hedging costs. Banks had substantial losses attributable to CVA during the 2007–08 financial crisis. Their exposures to certain counterparties (eg, monoline insurers) increased at the same time that the credit spreads of the counterparties widened (wrong-way risk). This caused the CVAs to increase very substantially, inflicting large losses on the banks, especially to those that were not hedging CVA actively. The banks that attempted to hedge their CVAs during the crisis found difficulties due to the illiquidity and extreme volatility of certain markets. The Basel Committee on Banking Supervision (BCBS) found that roughly two thirds of the banks' counterparty credit risk losses during the financial crisis were attributable to CVA mark-to-market losses, and only one third to counterparty default losses.[8]

The stress test of CVAs requires that a bank:

- ☐ stress the value of underlying trades to determine the stressed exposures to the derivatives counterparties;
- ☐ stress the credit spread curves of the counterparties;
- ☐ stress the losses caused by counterparty default events; and
- ☐ stress dynamic hedging losses.

The default losses are usually stressed via a copula model where the systematic factor driving the copula is a variable that represents a stressed credit environment. These copula models are usually called incremental default risk (IDR) models since they aim to estimate default losses that are incremental to the stressed mark-to-market losses.

The effects of stressed exposures and stressed counterparty credit spreads have to be calculated simultaneously in order to capture their joint impact. Below, we illustrate the large potential impact of cross-convexity and wrong-way risk on CVAs using a stylised scalar and unilateral calculation.

Example:

$$\mathrm{CVA} = -\mathrm{E} \cdot \mathrm{s}$$

where E is the exposure of the bank to the counterparty and s is the credit spread of the counterparty.

The sensitivity of the CVA to changes in the spread of the counterparty is –E. The sensitivity of the CVA to changes in the exposure to the counterparty is –s. A bank hedging CVA will take hedging positions of sizes E and s to hedge counterparty spread and counterparty exposure, respectively.

Introducing numbers on the example: suppose that, initially, E = 1000 and s = 0.03; the CVA is –30. Then, suppose that the market moves substantially and E = 1500 and s = 0.06; the new value of the CVA is –90. The hedge of the counterparty exposure provides a gain of 0.03 x (1500 – 1,000) = 15; the hedge of the counterparty credit spread provides a gain of 1,000 x (0.06 – 0.03) = 30. The total gain provided by the hedges is 15 + 30 = 45; the loss in the CVA is –90, and the net loss, after hedges, is –90 + 45 = –45.

The net loss of –45 is the effect of the cross-convexity of the CVA associated with the wrong-way risk (ie, counterparty exposure and spread go up together). This cross-convexity/wrong-way risk inflicted large losses on banks during the 2007–08 crisis because continuous dynamic hedging was difficult when markets were volatile and illiquid.

An important risk component of CVA is the cumulative losses associated with dynamic hedging. The combination of large counterparty credit exposures, wide counterparty credit spreads, cross-convexity between counterparty credit exposures and spreads, wrong-way risk, stressed market volatility and transaction costs can cause very substantial dynamic hedging losses. Those losses cannot be directly estimated by simple, static stress tests. They require sophisticated simulation models that aim to replicate the CVA hedging strategies over the relevant risk horizon. Typically, the CVA and its dynamic hedges are simulated over the market stress period and the probability distribution of potential hedging losses calculated. Those losses can be quite material relative to the sizes of the CVAs and of the underlying counterparty exposures.[9]

BANK-SPECIFIC VULNERABILITIES

Each bank, pursuing its business objectives, is exposed to certain specific risks. The design of the stress scenario should identify and stress-test those specific vulnerabilities. Within the context of the bank's portfolio, particularly in a multi-faceted trading portfolio, it is important to identify the set of circumstances that are particularly detrimental to the bank. It may be difficult to enumerate and identify those circumstances without a systematic scenario-generation framework for reverse stress-testing. Banking books are more directional than trading books. We know that bad economic environments will impair credit quality and hurt the banking portfolios. Such directionality does not exist so clearly in trading books. Naturally, market makers in bonds and equities tend to be long those risks in the inventories that they hold for trading. However, there are many other intervening risks in trading activities that are overlaid on those directional risks. The most detrimental scenarios for a trading portfolio may not be directional risks. They may be what are generally referred to as basis risks, such as the interest-rate curve spreads that harmed Long-Term Capital Management (LTCM) in 1998 (US$4 billion loss), or the energy forward curve spreads that harmed Amaranth hedge fund in 2006 (US$6.6 billion loss) or the risks between structured credit products that harmed JPMorgan Chase in 2012 (US$6 billion loss).

Importantly, vulnerabilities may also exist beyond the losses in the bank's market and credit portfolios – for example, circumstances that could prevent the bank's access to markets or to funding. In addition, circumstances that could require additional funding (via collateral posting, for example) or liquidation of assets at distressed prices need to be contemplated.

All risks ultimately need to be converted into loss numbers and then aggregated into a total loss result. The simplest mechanism to aggregate stress tests is to sum up all the stress losses across all risk types. This may not be a proper way to aggregate stress losses if the objective is to obtain a realistic assessment of the total stress loss. A mechanism to allow some diversification across risks is necessary. Again, copula model approaches can be useful for risk aggregation when applied with adequate conservatism.[10]

Intrinsically related to all the above is the confidence level or severity of the overall stress-test exercise. A stress-test number that is not linked to an assessment of its likelihood is less useful. Also, if the stress test is to be repeated in the future, it is desirable to have consistency in the likelihood of the stress test. This enhances comparability of the stress-test results over time.

Finally, financial crises present endogenous market dynamics that are difficult for any single bank to stress test. The risk positions held by different financial institutions and the institutions' actions during the crisis determine market dynamics that may be difficult to understand and forecast *ex ante*. Sales of assets at distressed levels, de-leveraging, de-risking and counterparty risks create disturbances in the system that may ultimately evolve into a severe financial crisis. Bank supervisors in possession of consolidated risk measures and stress tests of all banks and other systemically important financial institutions (SIFIs) may be better positioned to assess those systemic risks.

CONCLUSIONS AND RECOMMENDATIONS

Stress testing is a powerful tool to measure risks and assess capital adequacy. It has been used successfully by US regulators since 2009, and has led to a substantial recapitalisation of the largest US banks. The stress-test and CCAR processes are conducive to a rigorous effort in data collection, aggregation and analysis. The exercise of translating a core macroeconomic scenario into detailed portfolio losses requires combining historical data, portfolio characteristics, forecasting and calculation capabilities. To accomplish their goal, US banks had to substantially upgrade their systems and modelling processes, including model development, documentation and validation.

The discipline created by the CCAR process is as important as, or perhaps more important than, the numerical results that it ultimately produces. The disclosed numbers are the tip of the iceberg and are the result of a substantial infrastructure at work.

We recommend certain improvements to the design of effective and realistic stress tests, especially for market and counterparty risks: an emphasis on the need for explicit consideration of the hedging and liquidity dynamics of trading portfolios, systematic reverse stress testing for identification of market risk vulnerabilities in complex trading portfolios and the simulation of dynamic hedging costs of CVAs.

Stress testing will continue to evolve and improve in the future. It is a major driver of banks' capital assessment and allocation, and thus it is important that we make the stress tests as realistic as possible to capture the true economic risks that the banks face. The correct measurement of the economic risks and the correct allocation of economic and regulatory capital are a fundamental discipline to generate proper economic incentives to orient banks' activities and to promote the stability, effectiveness and efficiency of the financial system.

The comments and ideas expressed in this chapter are solely the author's and are not intended to represent those of his employer, Morgan Stanley

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1 The CCAR is an annual process implemented by the FRB to ensure that financial institutions have robust, forward-looking capital planning processes that account for their unique risks, and sufficient capital to continue operations throughout times of economic and financial distress. As part of CCAR, the FRB evaluates institutions' capital adequacy, internal capital adequacy assessment processes (ICAAP) and their plans to make capital distributions, such as dividend payments or stock repurchases, or other actions that affect capital.

2 12 USC 5365(i)(1) and (2).

3 Regulation YY: 12 CFR Part 252; 77 FR 62378 10/12/2012.

4 *Bloomberg News* (2013).

5 CCAR, "Summary Instructions and Guidance", November 9, 2012.

6 See Pritsker (2013).

7 CVA is the mark-to-market value of the credit risk faced by the counterparties of over-the-counter (OTC) derivatives. In DFAST and CCAR, only the component of the CVA corresponding to the credit risk faced by the BHC is stressed. The component corresponding to the credit risk faced by the BHC's counterparties is not stressed. This approach is conservative because it excludes the CVA gains that the BHC would realise when its own credit spread widened in a stressed environment. For additional information on CVAs, see Canabarro and Duffie (2003).

8 Basel Committee on Banking Supervision 189, 2011, "Basel III: A Global Regulatory Framework for More Resilient Banks and Banking Systems", revised version, June.

9 See Canabarro (2013).

10 See Rosenberg and Schuermann (2005).

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11

On Operational Risk Stress Testing

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This chapter will introduce operational risk and its evolution, as well as common industry practices in operational risk management. It will start by providing a brief background of operational risk and stress testing, followed by a systematic overview of the structures of supervisory and bank idiosyncratic scenarios. Common and useful methodologies in the construction of bank idiosyncratic scenarios will then be articulated. Related post-operational risk calculation work, such as the operational risk model capital buffer, reporting and effective challenge, will be addressed in the final section.

BACKGROUND TO OPERATIONAL RISK STRESS TESTING

History of stress testing

The Federal Reserve expects big, complex bank holding companies (BHCs) to hold sufficient capital to continue lending to support real economic activity, even under adverse economic conditions. Stress testing is one tool that helps banks' supervisors measure whether a BHC has sufficient capital to support its operations throughout periods of stress. The Federal Reserve previously emphasised the use of stress tests as a means of assessing capital sufficiency under stress during the 2009 Supervisory Capital Assessment Program (SCAP) and the 2011 and 2012 Comprehensive Capital Analysis and Review (CCAR) exercises.

In the aftermath of the financial crisis, the Dodd–Frank Wall Street Reform and Consumer Protection Act (DFA) of 2010 was enacted by Congress. The DFA requires the Federal Reserve to carry out an annual stress test of large BHCs and all non-bank financial companies designated by the Financial Stability Oversight Council (FSOC) for Federal Reserve supervision, to evaluate whether they have sufficient capital to absorb losses resulting from adverse economic conditions. The DFA also requires BHCs and other financial companies supervised by the Federal Reserve to conduct their own stress tests. The Federal Reserve adopted rules implementing these requirements in October 2012. Under the rules, 18 BHCs were part of the DFA supervisory stress tests in 2013. This number was increased to 29 for the 2014 CCAR.

History of operational risk measurement and management

Globalisation and deregulation in financial markets, combined with advances in financial technology, have introduced greater complexity into the activities of banks, and therefore their risk profiles. These reasons underscore banks' and supervisors' growing focus upon the identification and measurement of operational risk. Events such as the September 11 terrorist attacks, and rogue trading losses at Société Générale, Barings, AIB, UBS and National Australia Bank, have served to highlight that the scope of risk management extends beyond merely market and credit risk. The list of risks (and, more importantly, the scale of these risks) faced by banks includes fraud, system failures, terrorism and employee compensation claims. These types of risk are generally classified under the term "operational risk". The identification and measurement of operational risk is a real and live issue for modern banks, particularly since the decision by the Basel Committee on Banking Supervision (BCBS) to introduce a capital charge for this risk as part of the new capital adequacy framework

Evolution of operational risk

Operational risk, defined as "the risk of loss resulting from inadequate or failed internal processes, people and systems or from external events (including legal risk)",[1] is an old concept for banks. For many years, operational losses have been reflected on bank's balance sheets. These losses materially affect the soundness and operational efficiency of all banking activities and all business units. However, there has not been much precedent for measuring operational risk because of a generally scarcity of data. Even when there are data available, the history only dates back two or three years.

Although extensive work in attempting to measure operational risk has been carried out by various academics and authors, internal operational risk data is far from abundant for most banks. While there has latterly been a choice of several databases for external loss data, further work is required to determine how banks should adjust these to accommodate the fact that they originated in different size and control environments. In addition, in order to disguise control failures that may lead to capital penalties, some banks do not always accurately report the correct data, further affecting the accuracy of operational risk data. In addition, for most risk loss data, the collection process is manual, which leaves even greater room for errors and further downgrading of data quality.

Operational risk events have an extremely diverse set of causes, including fraud, improper business practices and product flaws, failures of technology, employment discrimination, transaction and execution errors, as well as natural disasters and terrorism. As a result, operational risk data coverage must include, *inter alia,* a broad spectrum of information regarding sources of internal weaknesses, clear definitions of "start" and "end" event dates, precise classification of loss amounts, recovery procedures and duration, and much more. Therefore, operational loss databases need to be significantly more comprehensive than those required for accounting restatements, and increasingly robust with regard to qualitative data.

Table 11.1 summarises the wave of operational risk events and losses. It is reported that the total operation loss was US$28.4 billion in 2011 and US$17.97 billion in 2012. The table demonstrates the scale and increasing severity of operational risk events.

Basel II and the various supervisory bodies of the countries have prescribed various soundness standards for operational risk management for banks and similar financial institutions. To complement these standards, Basel II has given guidance on three broad methods of capital calculation for operational risk (details of which will be provided later in the chapter).

- ☐ Basic indicator approach, based on annual revenue of the financial institution.
- ☐ Standardised approach, based on annual revenue of each of the broad business lines of the financial institution.
- ☐ Advanced measurement approaches (AMA), based on the inter-

Table 11.1 Selected operational loss events

Organisation	Location	Loss (US$ billion)	Trigger
Madoff Investment Service	US	50	Securities fraud
JP Morgan	US	13	MBS, security fraud
Bank of America	US	8.5	Security fraud
Wells Fargo	US	8.4	Concealed losses
Societe Generale	France	7.8	Unauthorised trading
Fairfield Greenwich Group	US	7.5	External fraud
RBS	UK	4	Misleading shareholders
Petters Group Worldwide	US	3	Records falsified
Barclays	US	2.98	Money laundering
Siemens AG	Germany	2.8	Bribes and kickbacks
Credit Suisse Group	Switzerland	2.7	Pricing mislead
VISA International	US	2.3	Anti-trust violations
JP Morgan	UK	2	Unsupervised trading
HSBC	US	1.921	Money laundering
CITI Group	China	1.9	Unauthorised trading
Ascot Partners	US	1.8	Lack of due diligence
TD Bank	US	1.4	Securities fraud
Suntrust	US	>1	Security fraud
Rabobank Group	Switzerland	1	Interest-rate manipulation
Bank of China	China	1	Funding terrorism
Citi	US	0.97	Security fraud
Union Bank of Swizerland	US/Switzerland	0.89	Unauthorised trading
Wells Fargo	US	0.87	Security fraud
Standard Chartered	US	0.667	Money laundering
ING	US	0.619	Money laundering
Credit Suisse Group	US	0.536	Money laundering
RBS	US	0.5	Money laundering
Barclays	US/UK	0.5	Libor rigging
Diebold	US	0.48	Bribery in foreign country
Lloyds Banking Group	US	0.35	Money laundering
Royal Bank of Scotland (RBS)	UK	0.18	IT failure
HSBC	UK	0.07	Employee taking advantage of company

nally developed risk measurement framework of the bank adhering to the standards prescribed (eg, the internal measurement approach (IMA), loss distribution approach (LDA), scenario-based, scorecard).

The operational risk management framework should include identification, measurement, monitoring, reporting, control and mitigation frameworks for operational risk.

CCAR, advanced methodologies

The stress-testing programme of the 2014 CCAR requires the participation of 29 US banks with more than US$50 billion in assets annually. Banks are asked to test the effect of various macroeconomic scenarios against their own operational risk-loss profile. These scenarios focus on economic events, such as a contraction in real GDP, a US equity price collapse and a US house price slide. Recessions in Europe and Asia are also included.

Although the Fed conducted stress-testing exercises during the financial crisis, this new, annual operational risk stress-test programme grew out of a provision in the DFA that requires the Federal Reserve to stress test non-bank financial companies as well as BHCs with more than US$10 billion in assets annually. The essence of the CCAR practice is to discover macroeconomic dependency (eg, cyclicality pattern) and underlying operational risk events, and hence be able to forecast losses from operational failures in any specific scenario. This framework will be articulated in more detail in the section on why CCAR is different, later in this chapter.

FED AND IDIOSYNCRATIC SCENARIOS

Structure of Fed scenarios

As a part of the annual CCAR practice, the Fed provides three sets of values for 14 domestic and 12 international macroeconomic variables for 12 quarters forward (representing the supervisory baseline, adverse and severely adverse scenarios). This is to ensure that institutions have robust, forward-looking capital planning processes that account for systemic risks and sufficient capital to continue operations throughout times of economic and financial stress. A comprehensive list of these Fed variables is displayed in Table 11.1.

Table 11.2 Federal Reserve variables for supervisory scenarios

	Supervisory scenario: domestic	**Supervisory scenario: international**
1	Real GDP growth	Euro area real GDP growth
2	Nominal GDP growth	Euro area inflation
3	Real disposable income growth	Euro area bilateral dollar exchange rate
4	Nominal disposable income	Developing Asia real GDP growth rate
5	Unemployment rate	Developing Asia inflation
6	CPIilnflation rate	Developing Asia bilateral dollar exchange
7	Three-month Treasury rate	Japan real GDP growth
8	Five-year Treasury yield	Japan inflation
9	10-year Treasury yield	Japan bilateral dollar exchange
10	Prime rate	UK real GDP growth
11	BBB corporate yield	UK inflation
12	Mortgage rate	UK bilateral dollar exchange
13	Dow Jones total stock market index	
14	House Price Index	
15	Commercial real estate price index	
16	Market volatility index (VIX)	

Figure 11.1 shows an example of the baseline and adverse GDP scenarios provided by the Fed for the CCAR 2013 practice. The structure of the adverse path starts with a six-quarter trough, representing a dip followed by a recovery after the sixth quarter. This structure represents a less likely but more severe economic outlook than the baseline scenario. Forecasting result under both scenarios will inform the institution that, although the firm will most likely incur a loss of US$X in the baseline scenario, it also has the potential to be hit by a US$X+Y unexpected loss in an unexpected scenario.

Structure of idiosyncratic scenarios

Apart from knowing that each bank operates in geographies with unique economic trends, different portfolio concentrations and sophisticated levels of controls, other than the systemic risk view that will be revealed by the Fed scenarios, BHCs are also required to select local macroeconomic variables, events, etc, and form idiosyncratic scenarios. These scenarios enable the company to assess

Figure 11.1 Structure of national GDP forecast by the Federal Reserve

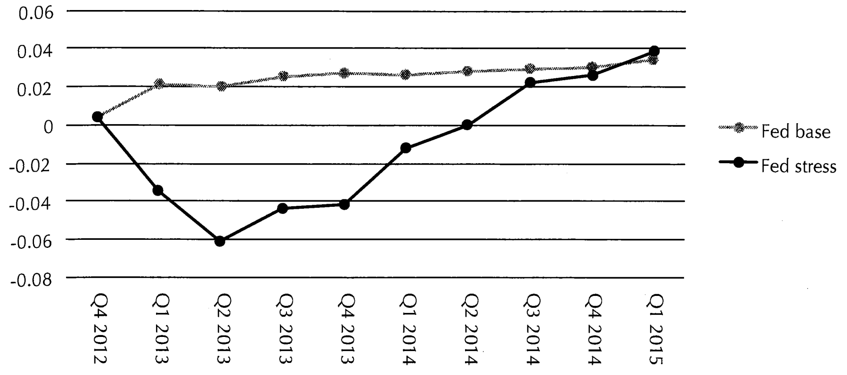
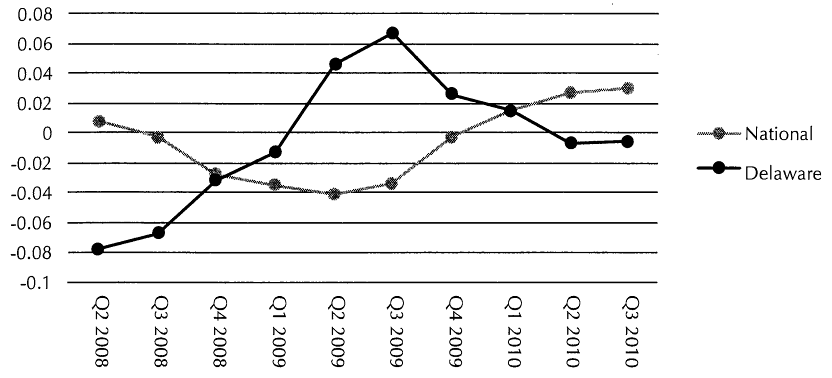


Figure 11.2 Structure of national and state GDP growth rate



bank-specific risks that are not captured by the Fed scenarios, and ensure that institutions have robust, forward-looking capital planning processes that account for their unique risks and sufficient capital to continue operations throughout times of economic and financial stress.

Commonly selected variables include state-level macroeconomic factors. Figure 11.2 shows a GDP path for the state of Delaware that actually deviated from the national trend. Other events, such as natural disasters and terrorist attacks can also be key components in an idiosyncratic scenario. It is believed that such events are more likely to occur in the footprints of certain banks than others. For more details on the structure and construction of idiosyncratic scenarios, please refer to Chapter 4 of this book, "Designing Macroeconomic Scenarios for Stress Testing".

One key challenge of creating idiosyncratic scenarios is that forecasted values are not provided by the Fed. Therefore, various data and modelling techniques could be used in the construction of idiosyncratic scenarios.

Data and modelling techniques in constructing idiosyncratic scenarios

Structured scenarios

Although there have been mature and sophisticated models for some macroeconomic factors, such as interest rates, by far the most commonly used data modelling approach for other macroeconomic factors is the time-series model autoregressive integrated moving average (ARIMA). This kind of model assumes that three components contribute to the determination of the forecasted macroeconomic factor value: (i) recent past observations of the macroeconomic factor value; (ii) recent past errors in the model; and (iii) the unmodelled portion, which is believed to be normally distributed.

Figure 11.3(a) Simulated scenarios and probability distribution

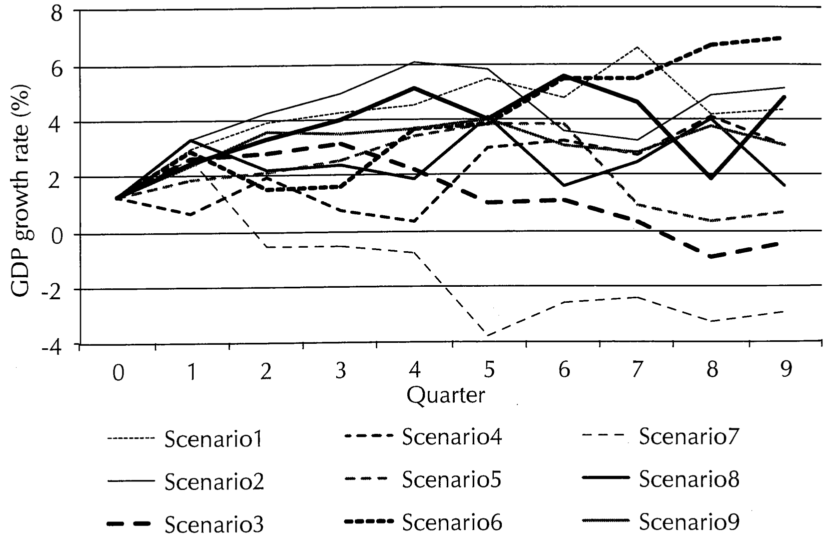
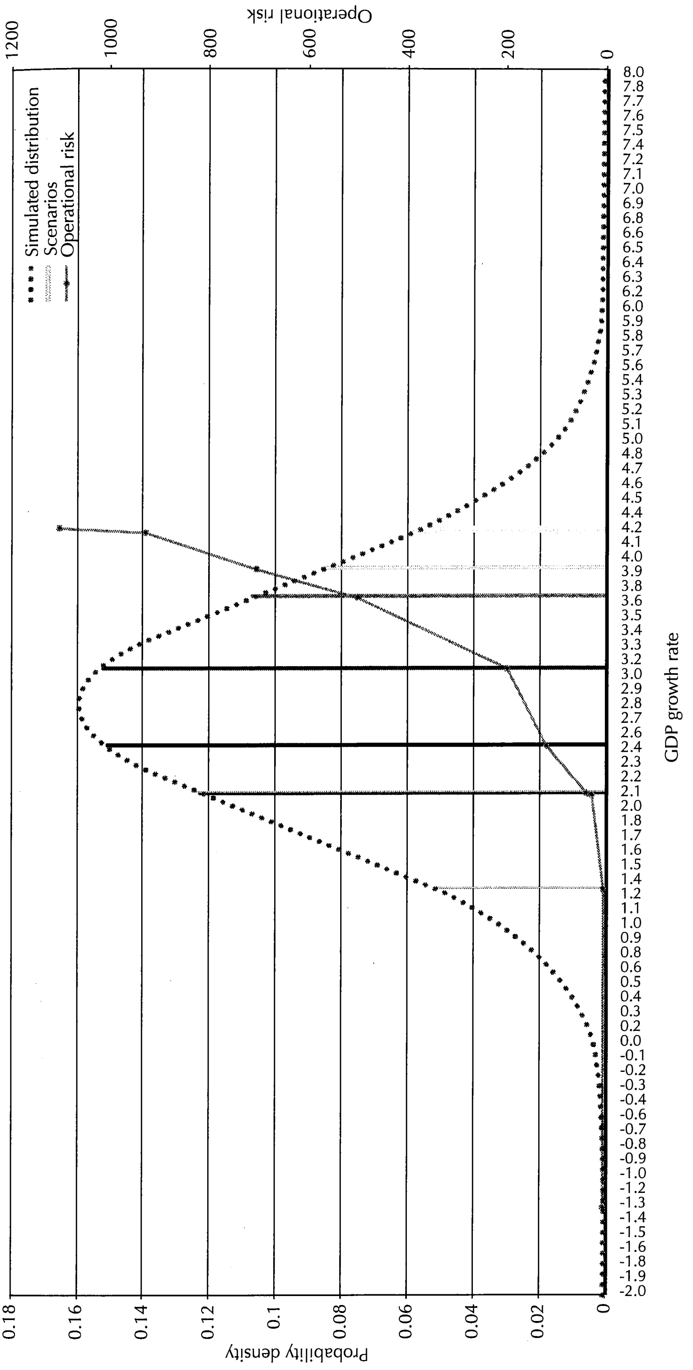


Figure 11.3(b) Simulated scenarios and probability distribution



Once a model is constructed and passes all statistical tests, a Monte Carlo simulation approach can be used in conjunction with the model to simulate numerous evolution paths of those variables. Figure 11.3(a) gives an illustrative example of this.

One advantage of simulating structured scenarios is that it is able to provide the probability of occurrence of a better scenario than the given one. For example, if the outlook of the GDP growth rate of New York State is believed to be no lower than –5% in the ninth quarter, hundreds of thousands of GDP paths can be simulated, and the percentage of paths with a ninth-quarter GDP growth <–5% over the total number of paths simulated is the probability of occurrence of such a scenario.

Provided that the probability of a scenario is determined, it is believed that the probability of a scenario drives the probability of an operational loss event. For example, a specific scenario can be fed into an operational risk model to determine the loss frequency as well as the loss severity (how such an operational model works will be illustrated in more detail in the following section). Then, the loss frequency and severity can be used to determine the operational loss amount. Through the use of the loss frequency and severity models, the link between scenarios and operational risks can therefore be built. As a result, the probability of a scenario is translated to the probability of the operational risk.

Synthetic data points

Operational risk can be linked to various kinds of idiosyncratic events that we do not have ample historical data to build forecasting models for, such as hurricanes, terrorist attacks, earthquakes and other rare disasters that can cause significant losses to the institution. These are perfect examples of when the synthetic data method can come into play. Assumptions of the occurrence of these events can be used directly to create synthetic scenarios that will drive operational losses.

Link to Fed scenarios

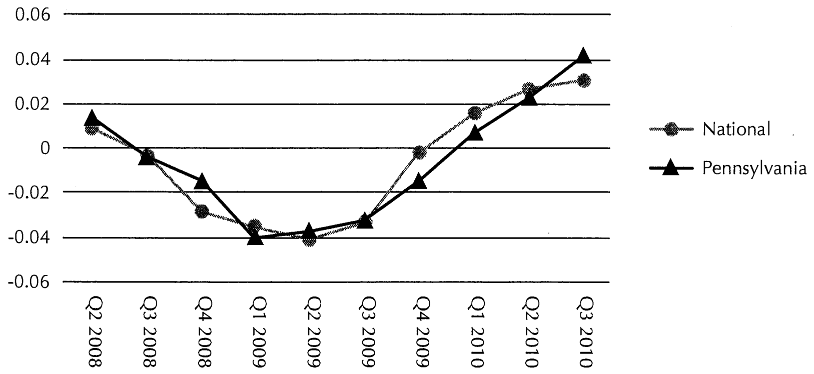
Local variables such as the House Price Index (HPI) of a Metropolitan Statistical Area (MSA) can be linked to the Fed scenario using regression or other approaches. One commonly used approach is linear regression, where a local variable is expressed as a scaled and shifted national Fed variable. The success of this approach is based on the fact that the local variable has a similar trend as the national variable. For example, in Figure 11.4 the GDP evolution trends of Pennsylvania and Maryland are very similar to the national trend. A linear regression approach may be appropriate if we assume this high correlation remains in the future. However, in the example in Figure 11.2, the GDP of Delaware moved in a different direction than the national GDP almost all the time. Therefore, linear regression in this case would be deemed inappropriate.

Non-linear regressions and more complex models can be used to create such a link. However, the business intuition behind these complex models is often opaque and hard to explain. It should also be noted that not only local macroeconomic factors but also certain loan/portfolio characteristics can be linked to national factors. For instance, the loan-to-value (LTV) ratio can be linked to the national HPI or CREPI indexes for forecasted values. The probability of default (PD) downgrades and upgrades can also be linked to macroeconomic factors. The net operating income (NOI) of a commercial real estate loan can also be adversely impacted by increased unemployment, a stock market decline or a subsequent increase in the vacancy rate.

Other

Management judgement and economic expertise can be used in the determination of a bank's idiosyncratic scenario without totally relying on statistical model forecasts. However, more usually,

Figure 11.4 Linking state GDP growth rate to national figures



economists and management overseeing scenario development will comment, critique and make logical changes to the statistical model output based on their knowledge and experience.

GENERAL APPROACHES TO MODELLING OPERATIONAL RISK

Under Basel II, operational risk charges can be calculated by using one of three methods (or approaches), which increase in sophistication and risk sensitivity: (i) the basic indicator approach; (ii) the standardised approach; and (iii) advanced measurement approaches.

The AMA approach

Bank-developed empirical models are allowed for the purpose of quantifying required capital for operational risk under the AMA. Banks can use this approach only subject to approval from their local regulators. Once a bank has been approved to adopt the AMA, supervisory approval is required in order to revert to a simpler approach. According to section 664 of original Basel Accord, in order to qualify for use of the AMA a bank must satisfy its supervisor, at a minimum, that:

- ☐ its board of directors and senior management, as appropriate, are actively involved in the oversight of the operational risk management framework;
- ☐ it has an operational risk management system that is conceptually sound and is implemented with integrity; and
- ☐ it has sufficient resources in the use of the approach in the major business lines, as well as the control and audit areas.

According to the BCBS' supervisory guidelines, an AMA framework must contain the use of four data elements: (i) internal loss data (ILD); (ii) external data (ED); (iii) scenario analysis (SBA); and (iv) business environment and internal control factors (BEICFs). While no particular modelling technique was specified for the AMA, LDA has been one of the most common approaches taken by the banking industry. With LDA, a bank first segments operational losses into homogeneous segments, called units of measure (see Basel Committee on Banking Supervision, 1988). Eight business lines are created from banks' activities: corporate finance, trading and sales, retail banking, commercial banking, payment and settlement, agency services, asset management and retail brokerage. Within each business line, gross income is a broad indicator that serves as a proxy for the scale of business operations and thus the likely scale of operational risk exposure within each of these business lines. See Table 11.3 for a detailed definition of units of measure.

For each individual measure, the bank then carries out a loss distribution that reflects its expectation of total losses that can materialise in a one-year horizon. Given that data sufficiency is a big challenge for the industry, annual loss figures are not an appropriate way of building annual loss distribution. Instead, a bank will develop a frequency distribution that describes the number of loss events in a given year, and a severity distribution that describes the loss amount of a single loss event. The frequency and severity distributions are assumed to be independent. The convolution of these two distributions then gives rise to the (annual) loss distribution, as shown in Figure 11.5. More details of this calculation under the CCAR framework will be given later in the chapter.

Approaches for non-AMA banks

AMA-light

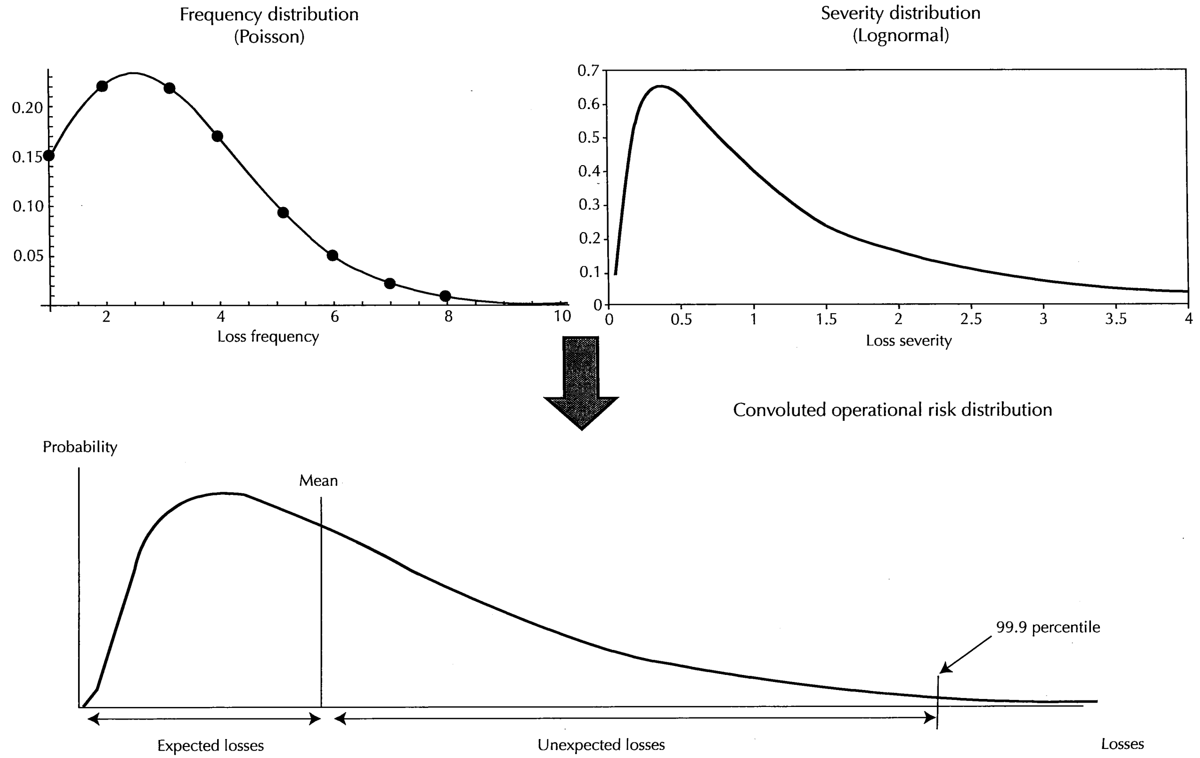
Non-AMA banks can still choose to follow the LDA approach and compute the operational risk distribution based on approximated

Table 11.3 Business units and business lines for operational risk calculations

Business units	Business lines*	Indicator
Investment banking	Corporate finance	Gross income
	Trading and sales	Gross income
Banking	Retail banking	Annual average assets
	Commercial banking	Annual average assets
	Payment and settlement	Annual settelment throughput
Others	Agency services	Gross income
	Retail brokerage	Gross income
	Asset management	Total funds under management

*A business line for agency services (custody, corporate agency and corporate trust) is intended to be included in the final proposal. An insurance business line may also be included in both the standardised and internal measurement approach, where insurance is included in a consolidated group for capital purposes.

Figure 11.5 Calculation of operational risk distribution using LDA



frequency and severity distributions. However, strict compliance to Basel rules can be relaxed. For example, homogeneity within a unit of measure may not be compulsory with limited data. Modelled frequency and severity distributions can be carried out at a more aggregated level because of loss data scarcity in granular lines of businesses. In an extreme case with considerable data scarcity, "top-of-the-house" loss frequency and severity models can be developed.

Standardised approach

In order to qualify for the use of the standardised approach, a bank must satisfy its regulator that, at a minimum:

- ☐ its board of directors and senior management, as appropriate, are actively involved in the oversight of the operational risk management framework;
- ☐ it has an operational risk management system that is conceptually sound and is implemented with integrity; and
- ☐ it has sufficient resources in the use of the approach in the major business lines, as well as the control and audit areas.

The definition of business lines is similar under the standardised approach, banks' activities are divided into eight business lines: corporate finance, trading and sales, retail banking, commercial banking, payment and settlement, agency services, asset management and retail brokerage. Within each business line, gross income is a broad indicator that serves as a proxy for the scale of business operations and thus the likely scale of operational risk exposure within each of these business lines. The capital charge for each business line is calculated by multiplying gross income by a factor (denoted by beta) assigned to that business line. Beta serves as a proxy for the industry-wide relationship between the operational risk loss experience for a given business line and the aggregate level of gross income for that business line (Table 11.4).

The total capital charge is calculated as the three-year average of the simple summation of the regulatory capital charges across each of the business lines in each year. In any given year, negative capital charges (resulting from negative gross income) in any business line may offset positive capital charges in other business lines without limit.

Table 11.4 Calculation of operational risk distribution using the standardised approach

Business line	**Beta factor**
Corporate finance	18%
Trading and sales	18%
Retail banking	12%
Commercial banking	15%
Payment and settlement	18%
Agency services	15%
Asset management	12%
Retail brokerage	12%

Basic indicator approach

The basic indicator approach is much simpler compared to the alternative approaches (ie, standardised approach (operational risk) and AMA), and this has been recommended for banks without significant international operations.

Based on the original Basel Accord, banks using the basic indicator approach must hold capital for operational risk equal to the average over the previous three years of a fixed percentage of positive annual gross income. Figures for any year in which annual gross income is negative or zero should be excluded from both the numerator and denominator when calculating the average. The fixed percentage "alpha" is typically 15% of annual gross income.

Why is CCAR different? Linking macroeconomic variables to losses

The major difference between CCAR and a traditional Basel AMA approach is the existence of a link of operational risk events to scenarios. The CCAR framework believes that the distributions of loss frequency and severity are not static; instead, they experience a considerable level of macroeconomic dependency. Therefore, under the CCAR framework, the scenario, which varies over time, determines dynamically the frequency and severity distribution for each unit of measure. These distributions are then aggregated to determine the operational risk in each forecasted period. Accordingly, the timeframe of the loss frequency estimation will be changed from one-year to one-quarter for nine quarters to comply with the CCAR requirement.

The statistics in Figure 11.6 show that operational losses did increase dramatically as the economy entered a recession. However, this result shows different stories for loss frequency and severity.

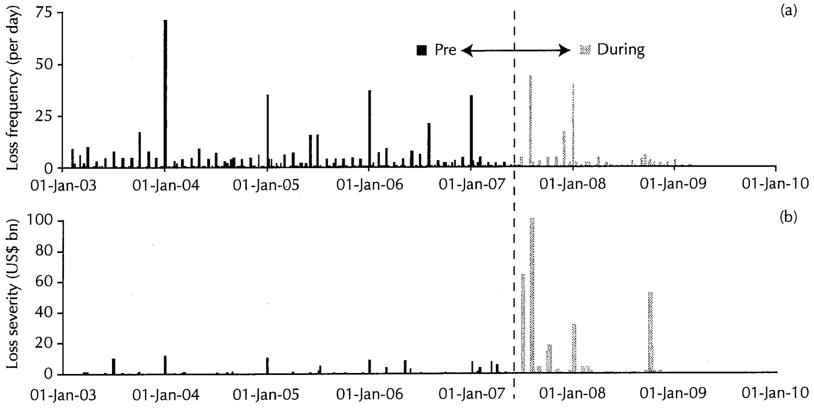
When markets start turning downward, both credit and operational risk officers have a tendency to "tighten their belts". As a result, the number of small loss events gets controlled and start to decrease. However, in the case of unauthorised trading events, for instance, as market conditions become more volatile, the rogue trader continues to increase their losses while they tries to trade themselves out of an ever-increasing hole. It becomes increasingly difficult to hide the accumulating losses. Once they are uncovered,

Figure 11.6 Cyclicality of operational risk

Operational loss data characteristics and parameters summary pre and during the credit crisis

	Pre	During
Date range	01/03–06/07	07/07–07/09
Average frequency/100 days	42	30
Average inter-arrival time	6.5 days	11.0 days
Currency	US$	
Number of losses	697	205
Average loss	0.17bn	1.80bn
Standard deviation	0.84bn	8.56bn
Coefficient of variation	4.95	4.75
Median loss	3m	60m
Modal loss	200k	72k
Maximum loss	9.3bn	85.0bn

Daily operational loss (a) frequency and (b) severity for the periods under investigation



Source: Esterhuysen *et al* (2010)

the losses are huge. This is reflected in the difference observed between pre and post-recession loss severities.

Lantsman and Cagan (2007) argue that operational risk losses are not related to decreases in economic activity, but are the result of increased economic activity prior to the recession, because big operational risk losses are less a reflection of a drop in business activity than a reflection of prior exuberance. Therefore, it is believed that stress testing could be more helpful than the AMA for firms seeking to better understand the origination of the risks they face.

Another place where the Basel II AMA framework falls down is around the fact that it only asks firms to model for one year. Others agree that performing the stress test over a period of nine quarters is valuable. The stress-testing exercises are much more valuable, because they look at a two-year time horizon and ask not just whether a firm can withstand a severe shock, but also whether it can dig its way out of the hole and recover the capital fast enough.

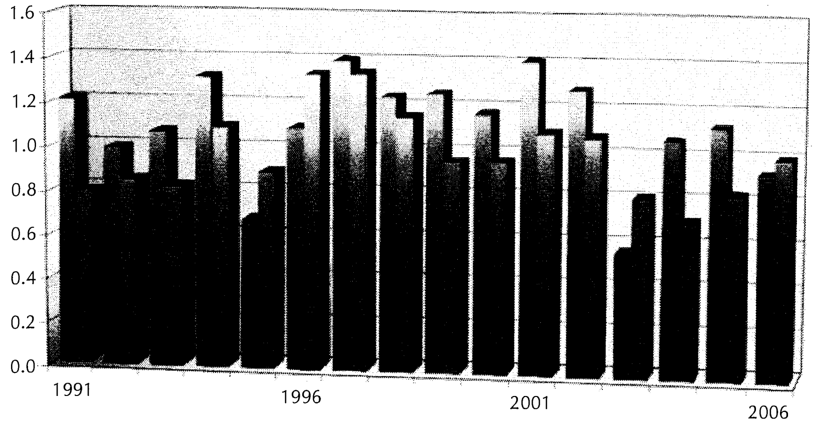
Understanding the systemic nature of operational risk by exploring stress testing is only half the answer. Firms need to better understand their own idiosyncratic risk as well. As mentioned earlier when looking at the Fed scenario, while there might be general correlations, individual organisations will have specific factors that determine how these correlations are exhibited. For example, an internal fraud might have been made worse by a particularly poor technology security system, or there might have been a change of leadership in part of the organisation responsible for gaps forming in the product-approval process.

It has been shown that the Chicago Board Options Exchange (CBOE) Volatility Index (VIX), as the standard measure of market volatility, provides extraordinary indication of operational risk. This relationship is demonstrated in Figure 11.7. Results in the remainder of this section are taken from Lantsman and Cagan (2007).

The CBOE defines the VIX as "a key measure of market expectations of near-term volatility conveyed by S&P 500 stock index option prices."[2] The VIX tracks investor sentiment and is reflective of what is happening in the markets. It is believed that there are certain categories of risk types that might track alongside market volatility.

- ❑ *People risk:* The risk of a loss intentionally or unintentionally caused by an employee (ie, employee error, employee misdeeds)

Figure 11.7 Cyclicality of operational risk



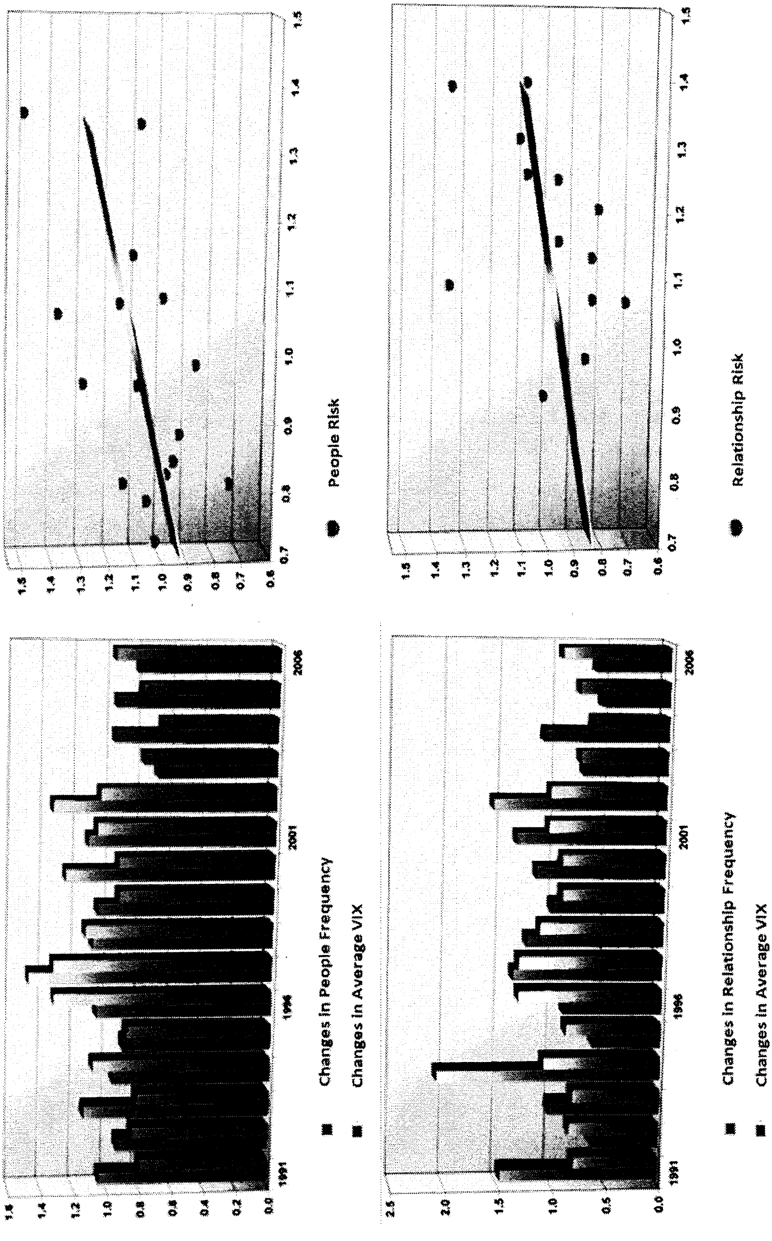
Source: Lantsman and Cagan (2007)

or involving employees, such as in the area of employment disputes. This risk class covers internal organisational problems and losses.

- ☐ *Process risk:* Risks related to the execution and maintenance of transactions, and the various aspects of running a business, including products and services.
- ☐ *Relationship risk:* Losses arising from the relationship or contact that a firm has with its clients, shareholders, third parties or regulators.
- ☐ *Technology risk:* The risk of loss caused by a piracy, theft, failure, breakdown or other disruption in technology, data or information; also includes technology that fails to meet business needs.
- ☐ *External risk:* The risk of loss due to damage to physical property or assets from natural or non-natural causes. This category also includes the risk presented by actions of external parties, such as the perpetration of fraud or, in the case of regulators, the execution of change that would alter the firm's ability to continue operating in certain markets.

Figure 11.8 demonstrates the results of a regression analysis that was performed to illustrate the tracking phenomenon between the VIX and the "people risk" class. There is a 60% concordance between the

Figure 11.8 Changes in total frequency of operational risk loss events versus changes in the average VIX



Source: Lantsman and Cagan (2007)

two categories. This represents a statistically significant tracking phenomenon between the two VIX and loss events.

Figure 11.8 also demonstrates the results of a regression analysis that was performed to illustrate the tracking phenomenon between the VIX and the "relationship risk" class of loss events. There is a 36% concordance between the two categories. This is significantly less than the 60% seen previously with the "people risk" category, but still demonstrates a notable tracking pattern.

It is generally believed in the credit risk world that market booms lead to "irrational exuberance" and a certain laxity in lending standards that can create losses later on when market conditions turn downward. This is also true for operational risk and business practices. The operating environment and control structure of a financial institution may become "more fluid" and "adaptive" during exuberant times, when the implementation of controls might be viewed as counter to growth and entrepreneurship. With the identification of "people risk" losses that are particularly tracking market volatility, it will become possible for risk managers to more accurately and astutely track potential weaknesses within their organisations, and seek effective ways to cover uncontrolled, unremediated risks.

The CCAR framework enables the assessment of the magnitude of operational risk, together with the likelihood of occurance of a macroeconomic scenario, and therefore assist risk managers to determine the amount of provision, required risk buffer and additional buffer needed for potential operational risk events.

MODELS FOR LOSS FREQUENCY AND SEVERITY

In this section, we will focus on the AMA/AMA-light approach for CCAR. The critical factor before modelling the frequency and severity is data collection. Critical information includes name of business unit, name and date, number of annual events and maximum of loss that could occur. Such an information aggregation example is given in Table 11.5, where it is necessary for each cell to be filled out. The comprehensiveness of this information is the key to the next modelling steps.

Table 11.5 Example of operational risk information collection sheet

Business units	**Business lines**	**Loss event category**	**Estimated annual numer of events**				
			20–100K	**100K–1M**	**1M–10M**	**10M–50M**	**Maximum single event loss**
Banking	Commercial banking	Damage to physical assets (DPA)					
		Business disruption and system failures (BDSF)					
		Execution delivery and process management (EDPM)					
		Internal fraud (IF)					
		External fraud (EF)					
		Employment practices and workplace safety (EPWS)					
		Client products and business practices (CPBP)					

Regression models to link macroeconomic variables to loss frequency

The definition of the loss frequency for operational risk is the number of loss events in a given year. In addition, common types of model that are used to model such a process are the Poisson process and the negative binomial process.

In the Poisson case, the loss frequency obeys a Poisson distribution with an expected value of λ, meaning that the most likely number of loss events in a year is λ, with certain probabilities being greater or smaller than λ. The likelihood of having k loss events in a year can be calculated as:

$$\Pr(X = k) = f(k;\lambda) = \frac{\lambda^k e^{-\lambda}}{k!}$$

Under the CCAR framework, based on the cyclicality analysis illustrated in the previous section, can be linked to the evolution of VIX in the simplest, linear way as $\Delta\lambda = c{\cdot}\Delta VIX$ + intercept + ε. The regressed loss frequency of client products and business practices (CPBP) is shown in Figure 11.9.

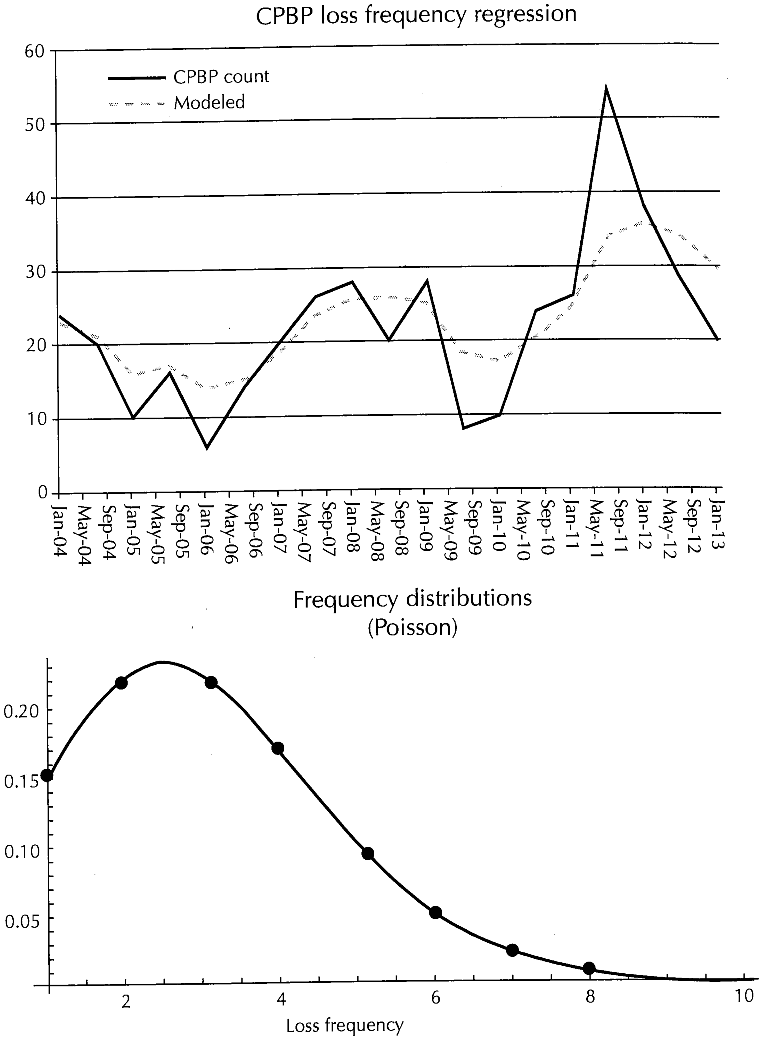
Researchers and practitioners have also found occasions where the one-parameter Poisson process is insufficient to capture some types of operational risk where macroeconomic environment affects the expected loss frequency and its volatility differently. The two-parameter negative binomial process is often considered to deal with such kind of situations. The likelihood of having k loss events in a year can be calculated as:

$$\Pr(X = k) = f(k;r,p) = \begin{pmatrix} k+r-1 \\ k \end{pmatrix} (1-p)^r p^k$$

The mean and variance of the negative binomial distribution can also be linked to macroeconomic factors to facilitate stress testing.

In addition to the regression technology, we would like to note that operational data collection is always a big challenge across the industry. This is partially because operational loss can take a very long time to realise. However, operational data is usually recorded on the event recognition date. The time stamp of the loss recognition will affect the relationship between the macro variables with loss. Practitioners may also consider relating leading macroeconomic indicators to account the lag between the recognition of operational risk event and the recognition of operational loss.

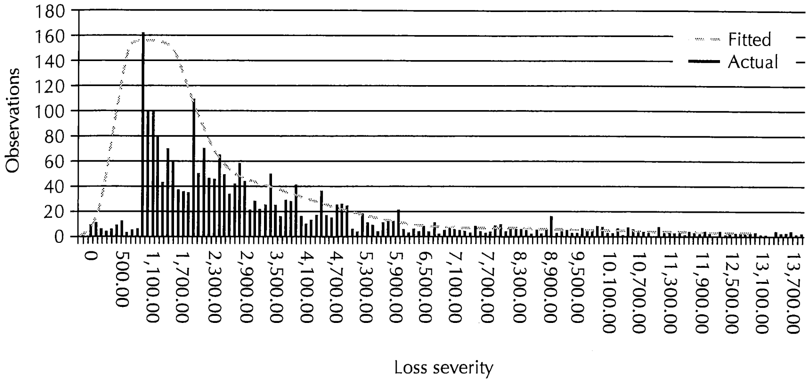
Figure 11.9 Regressed loss frequency of CPBP



Regression models to link macroeconomic variables to loss severity

Common distributions used in loss severity modelling include, but are not limited to, lognormal distribution, exponential distribution, Pareto distribution, etc. Business input loss data/estimates will be fitted by one of these distributions. An illustrative example of such a fitting is displayed in Figure 11.10.

Figure 11.10 Regressed loss severity



Under the CCAR framework, distribution parameters (the mean and variance) can be linked to macroeconomic indicators. For example, if lognormality is assumed for the loss severity of a certain unit, the mean value of this lognormal distribution can be expressed as a linear function of macroeconomic variables. Therefore, as the economy enters a recession defined by deteriorating macro factors, the mean value of loss severity, which is driven by those macro factors, will go up, resulting in an increased operational loss estimate. However, the resolution of this analysis is highly dependent on data quality. In other words, practitioners need to do a better job in data management and maintenance to promote this model.

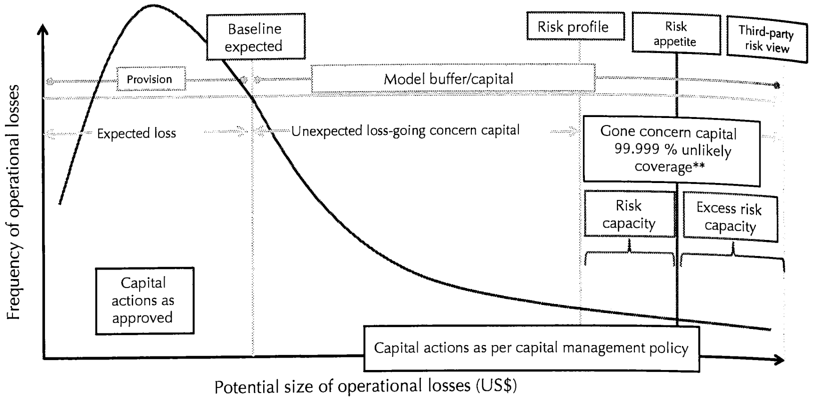
Complex aggregation

There are several ways to calculate the final operational risk. The LDA methodology convolves the loss frequency distribution with the loss severity distribution to achieve the operational loss distribution. Conducting a numeric Monte Carlo simulation separately on the loss frequency and severity will also provide an estimate of the operational loss distribution. An example of the loss distribution is given in Figure 11.11.

Based on the loss distribution, the expected loss/50th/75th/90th/other percentile loss can be calculated and used as the forecasted loss. In addition, these forecasts will change as changes in macroeconomic factors drive the changes in the loss frequency and severity.

However, some practitioners may find the convolution/Monte

Figure 11.11 Typical operational loss distribution


Baseline expected
Risk profile
Risk appetite
Third-party risk view
Provision
Model buffer/capital
Expected loss
Unexpected loss-going concern capital
Gone concern capital 99.999 % unlikely coverage**
Risk capacity
Excess risk capacity
Capital actions as approved
Capital actions as per capital management policy
Frequency of operational losses
Potential size of operational losses (US$)

Carlo approach too complicated and time inefficient. A fast route can be taken to multiply the mean/percentile loss frequency and mean/percentile loss severity to estimate the operational loss without having to assess the distribution, although it should be noted that this is a heuristic approach that may lead to biased estimation.

CAPITAL CALCULATION AND MODEL RISK BUFFERS

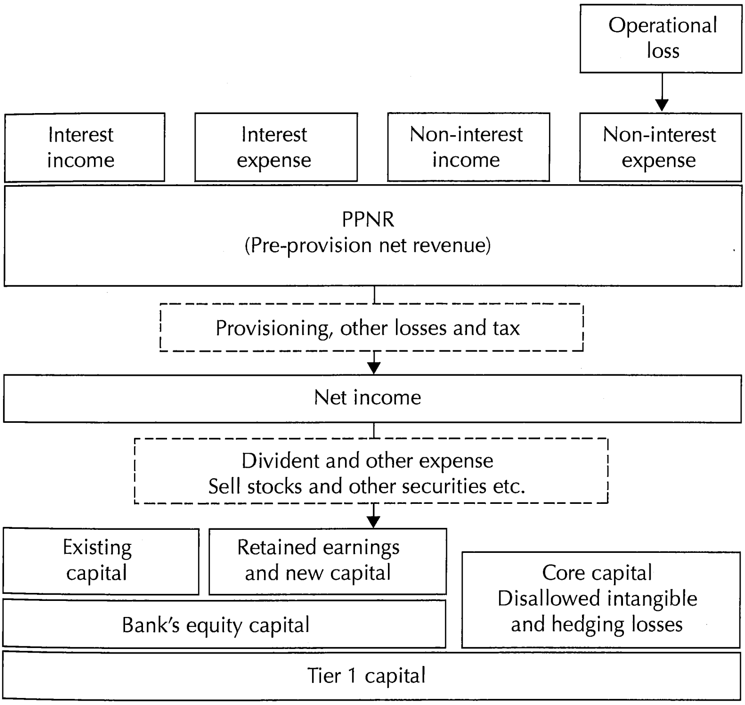
Model risk buffer assessment

As with all models, the operational risk model comes with a model risk. The operational risk model, and related assumptions, should be identified by the risk management department, and a model risk capital buffer assigned to this model based on its validation findings and deficiencies. However, there is a difficulty in assessing the correlation between the operational risk model and other models. Young *et al* have proposed a practical methodology that provides all stress-testing models with a consistent, objective, sustainable and transparent approach that is easy to assess by internal control. This approach calculates a risk score for each model based on model risk tiering and the validation result published by the risk management department. The model risk tiering represents the impact of a model on the financial statement, and the model validation result is generated through a comprehensive assessment of the modelling data, theory, implementation and any performance evaluation. This approach aggregates the model risks of individual models revealed by their backtesting results to the corporate level, and calibrates the corporate-level model risk to a bank's risk appetite. The total model risk buffer can be distributed to individual models based on their unique risk scores, which is a fair representation of models' intrinsic risks.

Capital calculation and reporting

In the Fed stress test required by FR Y-14A, operational risk expense appears as an entry of non-interest for all operational loss items, including operational losses that are contra revenue amounts or cannot be separately identified. Any legal consultation or retainer fees specifically linked to an operational risk event should be included in the operational risk expense, including all provisions to litigation reserves/liability for claims related to sold residential

Figure 11.12 Flow chart of operational risk in capital calculation


Operational loss
Interest income
Interest expense
Non-interest income
Non-interest expense
PPNR
(Pre-provision net revenue)
Provisioning, other losses and tax
Net income
Divident and other expense
Sell stocks and other securities etc.
Existing capital
Retained earnings and new capital
Bank's equity capital
Core capital
Disallowed intangible and hedging losses
Tier 1 capital

mortgages, and all litigation settlements and penalties in this line item and not any other items. Figure 11.12 presents how operational risk flows into the capital calculation.

Effective challenge

Effective challenge is proposed in the Fed SR Letter 11–7 as a critical analysis process carried out by objective, informed parties who can identify model limitations and assumptions, and produce appropriate changes. Incentives should be provided to ensure that effective challenges are separated from development. The challenging party should possess the technical knowledge to formulate a critique, as well as gain institutional information about the line of business. For example, the bank may form an independent model risk management department with knowledgeable validators. Validators will take part in critical discussions during the life cycle of model development and provide opinions on data quality, the developer's selected theory and methodology, as well as implementation. Institutions should ensure appropriate actions are taken based on effective challenge results.

For example, in the modelling of operational risk using the AMA-light methodology, a validator could find the data within a bucket does not display homogeneity. Suggestions will be given to the developers to assess the data, and also regarding the need for further segmentations. If so, the institution should guarantee that the developers further segment the portfolio instead of modelling on the heterogenetic portfolio.

CONCLUSION

This chapter first provided a brief history of operational risk and stress testing, followed by a systematic introduction of structures of the supervisory and the bank idiosyncratic scenarios. Common and useful methodologies in the construction of the bank idiosyncratic scenarios were articulated. Scenario development is critical because, under the CCAR framework, scenario drives operational risk events.

Based on this concept, the chapter then offered a thorough overview of general approaches to model operational risks, such as the AMA approach (the estimation of distributions of the loss frequency and severity) and other standardised approaches under the Basel framework. Techniques for linking macroeconomic scenarios to the AMA approach were illustrated in considerable detail.

The chapter argued that just developing an operational risk model is insufficient due to issues around model risk and capital impact, and presented a model risk buffer calculation option, as well as briefly summarising the process of capital calculation and reporting. Common practices and concerns on promoting an effective challenge to operational risk models were also addressed.

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1 This is the formal definition of operational risk quoted from http://en.wikipedia.org/wiki/Operational_risk.

2 Definition from Chicago Board Options Exchange (see www.cboe.com/micro/VIX/vixintro.aspx).

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12

Quantitative PPNR Modelling

Amnon Levy

Moody's Analytics

The Federal Reserve's annual Comprehensive Capital Analysis and Review (CCAR) assesses the capital adequacy of large, complex US bank holding companies (BHCs), and the practices used to assess their capital needs. As part of the CCAR process, institutions must demonstrate that they have sufficient capital to withstand a severely adverse operating environment and be able to continue operations. So far, institutions have mostly focused on developing quantitative models to describe potential credit losses, with expert judgement being more heavily relied upon for remaining balance-sheet items. However, with the Federal Reserve increasing the required sophistication and precision of CCAR submissions, there is a growing need to gather data and develop quantitative models for the broad set of balance-sheet and income statement items. Specifically, there has been more focus on developing quantitative models for pre-provision net revenue (PPNR), defined as interest and non-interest income, less interest and non-interest expense. PPNR represents a large number of disparate income statement items, ranging from interest income on loans, interest expenses related to retail deposits, compensation expenses, trading revenue and expenses related to operational risk. PPNR spans virtually every aspect of a financial institution, and the items can be disjointed in that available data, statistical properties and sensitivity to macroeconomic conditions can vary widely.

In this chapter, we will discuss various quantitative approaches for linking macroeconomic scenarios with PPNR items. Given the broad range of PPNR categories, each item requires special consideration when developing a modelling approach. The modelling approaches range in granularity and depend on the availability and quality of historical data, statistical properties of the line item, business use and application, and model consistency across balance-sheet and income statement items.

From a model accuracy perspective, granular, bottom-up style analysis can be ideal. For example, interest income on existing loans can be calculated by looking at the institution's existing portfolio and modelling segment-level, or even loan-level, details. Unfortunately, for the majority of PPNR items, this kind of approach is not an option at most institutions. Compensation expenses, for example, are not generally tracked at a granular level with sufficient history and in a convenient format. When this is the case, it is natural to consider top-down approaches, where line-item time series for the entire organisation is related to macroeconomic conditions. In many cases, one-time events (eg, the sale or purchase of a branch or line of business) will result in volatile line items unsuited to statistical inference. Correcting for these events is frequently impractical, and sometimes not feasible. For example, historical data on a stand-alone branch may not be available to offset and disentangle the effect of its sale and the macroeconomic conditions that drive variation in deposits. In such cases, peer approaches can be utilised, where data from similar institutions are used to understand how line items relate to macroeconomic conditions. By using a peer group, it is easier to isolate the systematic drivers as idiosyncratic events are averaged out. This allows for a better representation of future dynamics when leveraging the models for the purpose of projecting items based on various macroeconomic scenarios. The use of external data to augment and extend internal data has been recognised by the Federal Reserve to represent stronger practice. Of course, care must be taken to ensure proper model use.[1]

A separate consideration when using granular data is the extent to which segmentation aligns with business structure. In many cases, the organisation is not aligned with reporting categories (eg, FR Y-14A), with segmentation crossing business lines. This may result in challenges such as participation and buy-in by various stakeholders, especially if the customer segments are very distinct. This is related to consistency in modelling across balance-sheet items. For example, the modelling of new loan origination for the purpose of calculating interest income ought to be consistent with its modelling for the purpose of expected loss modelling.[2] This is a subtle but important point given that higher balance suggests higher interest income and higher losses, all else being equal. To make matters more complicated, an organisation should also recognise that loan origination impacts interest and non-interest expense as deposits, or other liabilities are needed to fund assets. These countervailing effects might motivate an institution to project higher loan origination for the purpose of interest income modelling, lower loan origination for the purpose of expect loss modelling and lower loan origination for deposit growth modelling, which is against the spirit of the stress-testing exercise. It is also inconsistent from an economic modelling perspective.[3] Relating this back to the extent to which segmentation aligns with business practice, the organisation must ensure that model ownership is well-defined and centralised when the model applicability crosses functional boundaries. To this end, many organisations are structuring PPNR groups that are explicitly responsible for modelling consistency and coordination across the organisation.

With modelling methodology being the primary focus of this chapter, the analysis will be organised as follows: the next section discusses quantitative granular approaches to relating PPNR items with macroeconomic variables, followed by a section that discusses top-down industry peer approaches to relating PPNR items with macroeconomic variables. We then explore applications of the model, and accounting for an organisation's strategic plans and incorporating expert judgement when projecting scenarios. The final section provides a recap and a glimpse of what the future might hold.

GRANULAR MODELS

This section discusses a number of granular, bottom-up PPNR models. Here granular refers to data available at a finer level than that reported at the bank or BHC level. Given that granular data are not typically available for non-interest income items, granular models are relevant for interest income and balance for categories such as commercial and industrial (C&I) and commercial real estate (CRE) loans, and, on occasion, for interest expense items. While institutions frequently have granular historical data related to interest expense, products change with sufficient frequency that it can be cumbersome to go down the route of developing a granular model.

With that in mind, C&I balance and interest income (related to two FR Y-14A line items) are used to illustrate granular modelling given that granular data are commonly available.

There are at least two broad approaches to modelling balance. The first directly models balance for various segments of the portfolio (eg, asset class, industry, maturity, credit rating), potentially having separate balance models for lines of credit and their usage. The second models various components of run-off and new origination for various segments of the portfolio. By explicitly modelling the components, one can ensure a more accurate estimate of balance-sheet and income statement dynamics. For example, when computing interest income, one can differentiate between interest earned on existing loans and newly originated loans (assuming availability of models that differentiate interest charged on existing and newly originated loans). It also allows for a higher degree of consistency between PPNR calculations and loss estimation. For example, it is possible to account for changes in interest income resulting from non-accruals.

The choice of the direct balance or component approach should depend on availability of data and analytics; modelling of run-off requires accounting for prepayment, amortisation and loss. The choice of segmentation clearly depends on available data, but should also depend on the institution's portfolio, along with the cross-segment variation in response to macroeconomic conditions.

Given that data availability is a major component of model design, the first part of the section will focus on data options and limitations, while the second part discusses a number of modelling considerations.

Data options and limitations

A number of data sources provide granular, loan-level data that can be segmented and provide a foundation for modelling balance, usage, new origination and interest charged on new origination. Modelling run-off can be approached through empirical methods, or analytically through explicit modelling of drivers such as prepayment, loss and accounting for amortisation and maturing assets for the existing book and newly originated assets.

Internal data for large C&I loans is frequently kept track of at a reasonably granular level. Institutions required to complete the FR

Y-14Q may have loan details for C&I loans larger than US$1 million going back a few years at best. While not sufficiently far back enough to build an econometric model, this data can provide the institution with an ability to model the existing balance by segment, and potentially have appropriate data to model run-off from maturity and non-accruals. In some cases, the institution may have terms and conditions on data, allowing for modelling of run-off coming from prepayment.[4] If sufficient internal data are not available, external data can be used as a supplement.

Moody's Analytics Credit Research Database (CRD) is an example of one dataset that contains information on C&I loans for non-public borrowers. The CRD consists of data contributed by over 45 financial institutions (including 15 US banks) and various external data sources. Participants of the CRD provide quarterly portfolio snapshots with facility and borrower-level data. The CRD contains data that can be used to infer time series dynamics of balance, new origination, interest charged on new origination and usage. In addition, the CRD contains details that allow for loan segmentation based on characteristics such as industry, credit quality or loan type (eg, term loan or line of credit).[5]

Modelling considerations

As discussed earlier, modelling approaches depend on the availability and quality of historical data, statistical properties of the line item, business use and application, and model consistency across balance-sheet items. For the purpose of this section, we assume that the organisation is structured so that models are coordinated across lines of business, and that segmentation decisions can be based on data considerations (eg, quality of historical data, statistical properties). With segmented data in hand, one can focus on the objective of designing models that can be applied to forecast changes in balance, usage, new origination and interest charged on new origination under various macroeconomic scenarios, including the baseline, adverse and severely adverse scenarios provided by the Federal Reserve, as well as custom scenarios that are specific to the institution.[6] These model outputs can then be used in the calculation of FR Y-14A items.

The steps in the model development process should include both quantitative methods and economic judgement. The objective is to choose a model specification for each segment that has strong predictive power that can be supported by economic judgement. Macroeconomic variables chosen by the FRB are candidates for explanatory variables in the regression analysis. However, there may be alternative variables that are relevant. For example, a portfolio heavily invested in oil companies should consider whether, say, an oil price index helps explain time series fluctuations in balance, or any of the other variables. It is important to recognise that different models will have varying sensitivity to macroeconomic conditions. For example, interest charged on new origination is typically more sensitive to credit spread indexes than a balance model. Balance tends to be much slower moving given that the loan book cannot be immediately rebalanced; the organisation must wait for the existing book to run-off. Thus, lagged macroeconomic variables frequently perform well in describing balance.

It is important to allow economic intuition to enter into the modelling process. Given the large number of candidate variables, one can generally find statistical outliers where coefficients have signs that make little sense. This will be discussed in more detail later in the chapter when expert judgement is incorporated into the analysis. Care must be given to ensure that the variables have appropriate properties (eg, stationarity, homoscedasticity), and that the properties are accounted for when making statistical inference. In addition, it is important not to over-fit the data, which is possible given that many of the CCAR variables describe common economic environments (eg, GDP and unemployment).

Transparency and parsimony are two additional properties that should be considered when proposing a model. Variables such as balance, usage, new origination and interest charged on new origination are persistent. Linear growth or autoregressive models are specifications that are natural choices in this context. The choice of growth model over an autoregressive model should be, in part, determined by whether the series exhibits a unit root. Using balance for term loans as an example, the autoregressive equation can be represented as something in the spirit of:

$$\text{Balance}_t = AR_B\left(\{\text{Balance}_{t-k}\},\{MV^{CCAR}_{n,t-k}\},\{SC_{m,t-k}\}\right)+\in_t$$

Also, for growth, the equation can be expressed as something in the spirit of:

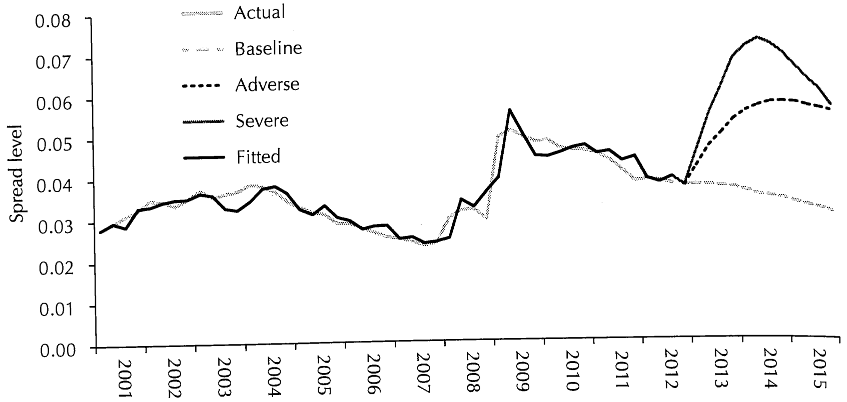
$$\text{Balance growth}_t = \frac{\Delta\text{Balance}_t}{\text{Balance}_{t-1}} = G_B\left(\left\{MV_{n,t-k}^{CCAR}\right\},\left\{SC_{m,t-k}\right\}\right) + \in_t$$

where $\{MV_{n,t-k}^{CCAR}\}$ are the selected set of macro and lagged macro variables used in the regression, $\{SC_{m,t-k}\}$ represents the set of segment and lagged segment characteristics (eg, maturity or average credit quality) and $\in_t$ represents an error term independent of the other explanatory variables. $AR_B(.)$ and $G_B(.)$ represent autoregressive and growth functions with parameters that need to be estimated. Ordinary least squares (OLS) can be used when the function is linear, or some version of generalised least squares, such as a weighted least squares, if some data points are measured with a higher degree of accuracy or if they are more relevant from an economic perspective. Non-linear specifications, such as panel quantile regressions, can also be explored. The chosen approach should consider the trade-off between accuracy and complexity.[7] In addition, care should of course be given to ensuring that the error term is well behaved and, if not, to ensuring that their behaviour is properly accounted for when making statistical inference.

In working through a specification, one should pool data to allow for robust statistical inference. For example, one can pool segments leveraging joint dynamics that are viewed to be common, allowing for a more accurate description of the relationship with macroeconomic variables. In other cases, it may make sense to estimate separate functions for each segment as the dynamics across segments are too different from one another. For example, term loans and lines of credit are frequently modelled separately, given that lines of credit face an additional dynamic of potentially being drawn down.

Under the direct balance approach, total interest-charged projections would be needed to compute interest income. Conceptually, the interest charged at each point in time would be a combination of interest charged on existing loans, and new loans. This is likely to be difficult given that the balance model does not differentiate between new and existing loans. Instead, a conservative approach (from the perspective of stressing PPNR) can be taken where existing spreads can be applied to all loans. After all, spreads on newly originated loans tend to increase during downturns. This can be seen in Figure 12.1, which provides spreads for a sample of newly originated C&I

Figure 12.1 C&I spread on newly originated term loans, fitted spread from spread growth model and spread projections based on Federal Reserve 2013 baseline, adverse and severe scenarios



loans from the CRD, along with fitted values and projections based on the Federal Reserve 2013 baseline, adverse and severe scenarios. By applying the spread associated with the last point in dataset, interest income will be lower under the adverse and severe scenarios.

It is not surprising that consistent application of the direct balance model across the balance-sheet and income statement (eg, when projecting credit losses) will result in similar issues to those described when differentiating between spreads on existing and newly originated loans. To avoid these challenges, the component approach can be used, where separate projections would be estimated for run-off and new origination for various segments. Functions similar to what was described for balance (ie, $AR_B(.)$ and $G_B(.)$) would be explored and estimated for each component. For the purpose of, say, interest income, spreads on newly originated loans would be associated with loans originated at each projected quarter and each segment.

An additional consideration when focusing on the component approach is its interaction with segmentation. This can be the case with new origination and spread charged on newly originated loans that feed into interest income projections. Another example is new origination for lines of credit, usage and spread charged on newly originated lines that also feed into interest income projections. Differing dynamics may prevail across interactive models that may be countervailing once segmentation is taken into account. These dynamics may be washed out and lost with the direct balance approach. For example, lines of credit tend to be drawn down as credit quality deteriorates. There is evidence to suggest that while smaller and lower-rated firms use their credit lines more intensively in general, larger and higher-rated firms were more likely to draw on their credit lines during the financial crisis of 2007–08.[8] A countervailing effect when calculating interest income on lines of credit is the more dramatic increase in rates charged to lower credit quality borrowers during the crisis. Thus, interest income may increase or decrease for various segments across the Federal Reserve's scenarios. Similar patterns prevail for term loans where the response to the crisis was more pronounced for smaller entities and financial firms. Accounting for these differing patterns clearly allows for a more accurate description of interest income. In addition, it permits more accurate loss estimation when these cross-sectional patterns in new origination and usage are explicitly modelled.

As a final note, robust validation must be integrated into the model development process, where performance is assessed both within sample and out of sample. It is important to recognise that use of external data does require additional analyses to ensure applicability to the institution. This can frequently be addressed by analysing dynamics for the, perhaps more granular, external data under segmentation that conforms to data available for the organisation, which allows for some level of statistical comparison.

TOP-DOWN INDUSTRY PEER MODELS

In this section, we will explore a number of top-down industry peer PPNR models. The models are presented through a set of case studies where specific PPNR items are analysed. As discussed, there are several reasons to use top-down industry peer models. To recap, most non-interest income and expense items are not consistently tracked at a higher level of granularity than what is reported publicly or in regulatory filings. Some interest income and expense items may have accurate granular historical data, but face the challenge that variation in product composition results in limited history, creating difficulties when attempting to quantitatively link variables with macroeconomic variables. Finally, idiosyncratic variation in some line items makes statistical inference problematic. By using a peer group, it is easier to isolate systematic drivers as idiosyncratic events are averaged out, allowing for a better representation of future dynamics as they relate to macroeconomic scenarios. The remainder of this section is organised as follows: the first part focuses on data options and limitations; the second discusses a number of modelling options and considerations.

Data options and limitations

Given the objective of designing a quantitative model to produce projections for the FR Y-14A form, the challenge becomes finding data both relevant and available over a sufficiently long history. Within the context of top-down models, several datasets are worth noting. Financial institutions required to complete the FR Y-14Q will have historical data with the same line items as the FR Y-14A. However, the data are not public, thus not appropriate for peer modelling. In addition, data will, at best, go back only to 2009. Given the limited history and idiosyncrasies in FR Y-14Q data, using additional data sources may improve the statistical soundness of the models. The following two data sources have proven to be useful.[9]

- ☐ FR Y-9C: Collected quarterly and reported publicly, the FR Y-9C is submitted at the consolidated level for the holding company and its subsidiaries. It is designed to parallel call reports for banks insured by the Federal Deposit Insurance Corporation (FDIC). The report consists of financial data (balance sheet, income statement and supporting schedules) for BHCs, savings and loan holding companies (SLHCs), and securities holding companies (SHCs). When projecting most PPNR components, the Federal Reserve uses data on historical revenue, and operating and other non-credit-related expenses reported on the FR Y-9C report.[10]
- ☐ Call reports: Call reports are similar to the FR Y-9C forms in that they contain basic financial data such as balance sheets and income statements. However, line items are reported on the bank level rather than the BHC level.

While the FR Y-9C and call report data have the benefit of containing a rich history for peer institutions, there is the disadvantage that line items do not align with many of the FR Y-14A line items. This issue is particularly relevant for the non-interest income and expense line items. In addition, FR Y-9C and call report data structures themselves change over time, with some line items dropped and others added. Finally, institutions have flexibility in choosing which line item to associate reporting various non-interest income and expenses, making peer comparisons difficult.

To address this challenge, institutions can aggregate line items by broader category classification comparable across the FR Y-14A and FR Y-9C (or call reports). To ensure the classification makes sense, one can compare the historical dynamics of the FR Y-14Q and FR Y-9C (or call report) over the (limited) historical data for one's organisation.

Modelling considerations

With a panel of peer data from the FR Y-9C and call report in hand, one can begin exploring the relationship between macroeconomic variables and industry peer PPNR category classification. It is important to recognise that it is unlikely for a single relationship to prevail across all PPNR categories. For example, CRE interest income is likely driven to a large degree by the CRE price index, which may not play as much of a role with C&I interest income or compensation expense. In addition, a separate modelling framework may be needed for the BHC and bank, with different macroeconomic drivers. This is relevant when the holding company contains a number of banks or other entities with substantive values for line items that feed into the category. Peer groups may need to be constructed for each entity level and each category; peers should be chosen to most closely resemble activities in that area. In addition, in some cases business lines might associate a different set of peers for the same line category classification. With these issues in mind, this section outlines several classes of specifications found to describe top-down peer relationships between many PPNR categories and macroeconomic scenarios.

There are many similarities between statistical approaches used in top-down peer approaches and those used in granular bottom-up approaches. However, important differences exist. First, one should recognise that there are differences across institutions used in estimating the model. While those behavioural differences ought to be minimised through proper peer selection, there will undoubtedly be variances that, when possible, need to be accounted for. Second, when developing autoregressive models, it is natural to explore the dynamics of items scaled by, say, assets. This scaling allows for easier comparison across peers. Otherwise, nominal series (ie, unscaled) when applied to autoregressive models, for example, tend to have observations of very different orders of magnitude, driven by the wide range of values that prevail on banks' balance sheets. Such a wide range in values makes statistical inference more complicated. If one models categories scaled by assets, a separate asset model is needed. The scaled model, along with the asset model and starting values, allows one to project the category. If one were to model line-item growth directly, rather than scaled values, the additional growth model for the numerator (eg, asset growth) is not needed.

We now turn our attention to the representation of top-down peer regression models. Since growth models are sufficiently similar to those described above in the granular case, our focus is entirely on autoregressive asset-scaled category models:

$$Category_{p,t} / Asset_{p,t} = AR\left(\begin{matrix} \left\{ Category_{p,t-k} / Asset_{p,t-k} \right\}, \\ \left\{ MV_{n,t-k}^{CCAR} \right\}, \left\{ PC_{p,t-k} \right\} \end{matrix} \right) + \in_{p,t}$$

where $Category_{p,t-k}/Asset_{p,t-k}$ represents a lagged asset-scaled category balance, $PC_{p,t-k}$ represents peer characteristics (eg, peer dummy), p represents peer and other variables are defined as above. Since some categories follow a seasonal process, the modelling approach may also include quarter dummies to capture possible cyclicality.

With the autoregressive scaled model estimated, we turn attention to modelling the scaling variable. If assets are used in scaling, growth models are a natural choice given that asset levels are not typically stationary. Asset growth would be applied to the scaled model projections in order to come up with category projections in dollar terms. Asset growth can be modelled as something along the lines of:

$$Asset\ Growth_t = \frac{\Delta Asset_t}{Asset_{t-1}} = G\left(\left\{ MV_{n,t-k}^{CCAR} \right\}, \left\{ PC_{m,t-k} \right\} \right) + \in_t$$

The spirit of this overall approach is in line with that of the Federal Reserve, where most PPNR items are categorised, scaled and modelled through an autoregressive process.[11]

As a final note for this section, and similar to the discussion in the section that outlines granular modelling approaches, robust validation ought to be integrated into the model development process, where performance is assessed both within sample and out of sample.

APPLICATION AND ACCOUNTING FOR THE OPERATING PLAN AND EXPERT JUDGEMENT

This section will discuss the mechanical application of the model for the purpose of scenario projections in a format in line with FR Y-14A line items, and approaches to accounting for an organisation's strategic plans and incorporating expert judgement into the projections.

The mechanical application of the model involves several steps. First, multiple models may need to be combined to generate projections. This was the case with the scaled autoregressive top-down industry peer models that needed to be combined with an asset growth model. Second, a starting point is needed for the growth and autoregressive models. Third, when categories are modelled, a decomposition schema is needed to allocate the category classification across the various FR Y-14A line items within the category. An organisation then needs to consider the extent to which strategic plans align with the quantitative model projections, and the degree to which they may want to consider adjustments or overlays so that the two align.

The discussion of the mechanical application of the models for projecting FR Y-14A items is presented within the context of the top-down industry peer model described above. This is of particular relevance for non-interest income and expense where autoregressive scaled category models and asset growth models need to be combined to estimate each of the nine-quarter projections. Future asset values can be estimated recursively, and then used to calculate the predicted category totals:[12]

$$\widehat{Category}_{p,t} = Categor\widehat{y_{p,t}} \,/\, Asset_{p,t} Asset_{p,t-1} \widehat{Asset}\; Growth_{p,t}$$

Here, hatted variables represent fitted modelled values. In some instances, the model might describe dynamics of an observed variable that does not exactly align with the required FR Y-14A item. This is the case with balance where the most precise data may be balance levels, which is different from the FR Y-14A required item that is averaged over the quarter. While the growth or autoregressive projection model can be applied to the starting average balance value, the organisation should recognise the limitation of the model's application.

The next step is the disaggregation of projections to the FR Y-14A line-item level. Disaggregation can be carried out proportionally based on the relative size of the FR Y-14A items. A more involved procedure would allocate the projection based on the proportion of variation coming from each FR Y-14A item – perhaps by leveraging the FR Y-14Q history.

Prior to deciding on the final set of models and projections, it is important to review results with economic judgement. There will be instances where seemingly similar variables will have opposite reactions to a macroeconomic stress. The challenge is to differentiate between legitimate candidate models and models with coefficients that are statistical outliers, and may even have coefficients with signs opposite to that which most closely represents reality and the spirit of the exercise. An example of two variables that seem similar, but have legitimate opposite reactions to stressed macroeconomic environments, are checking and time deposits. Figures 12.2 and 12.3 are based on call report data for the banking industry, and represent dynamics for checking and time deposits along with fitted modelled values and projections. The opposite reaction of checking and time deposits to the severe scenario is consistent with historical flight-to-quality patterns during economic downturns (checking), and movement toward higher paying investments (time deposits) during upturns.[13]

Turning our attention to model application and use, there are several issues worth thinking through. First, from a statistical standpoint, there is the question of the extent to which projections make sense given that historical data are used in estimation. For example, average C&I loan balance growth has been substantial since around the start of the century, in line with the substantial growth in the banking sector. It is questionable whether this level of growth is expected to persist in coming years. The model might provide good insight on co-movement between balance and macroeconomic conditions, but it may not provide a reasonable baseline projection. As an example, Figure 12.4 presents historic balance levels for a

Figure 12.2 Checking deposits, fitted deposits from growth model and projections based on Federal Reserve 2013 baseline, adverse and severe scenarios

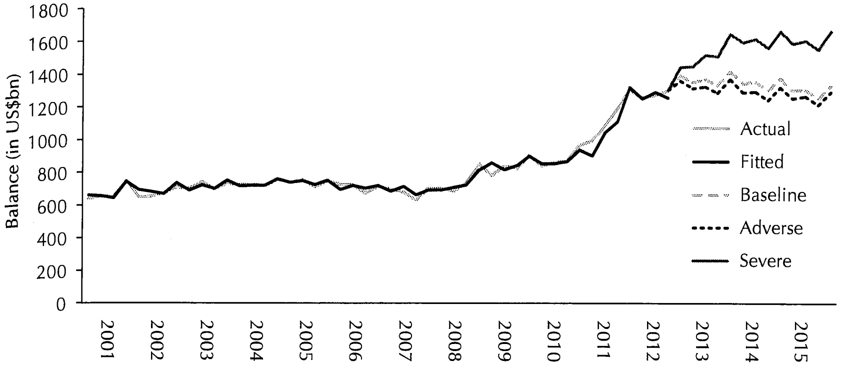
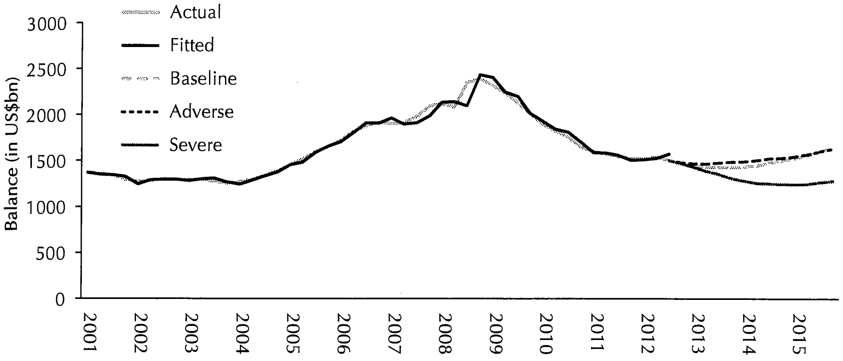


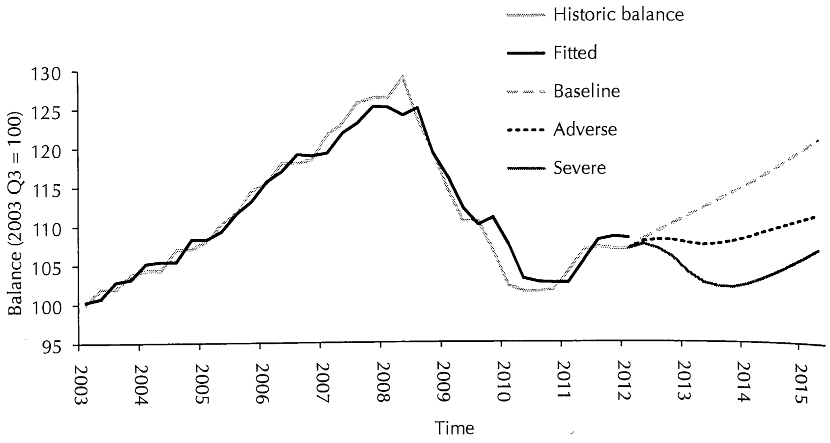
Figure 12.3 Time deposits, fitted deposits from growth model and projections based on Federal Reserve 2013 baseline, adverse and severe scenarios



sample of C&I loans, fitted values and projections for the Federal Reserve baseline, adverse and severely adverse 2013 CCAR scenarios, using data from Moody's CRD.

The time series dynamics conform to the dramatic pre-crisis growth in C&I lending, with a sharp reduction as the crisis unfolded and later recovery. Focusing on projections, the dramatic increase in balance under the baseline projection is striking. While the pattern conforms to historical patterns, it may not be in line with the institution's strategic plans. In fact, in this example, the baseline is sufficiently rosy, so much so that the adverse scenario looks rather

Figure 12.4 C&I balance levels (June 2003=100), fitted balance from balance growth model and balance projections based on Federal Reserve 2013 baseline, adverse and severe scenarios



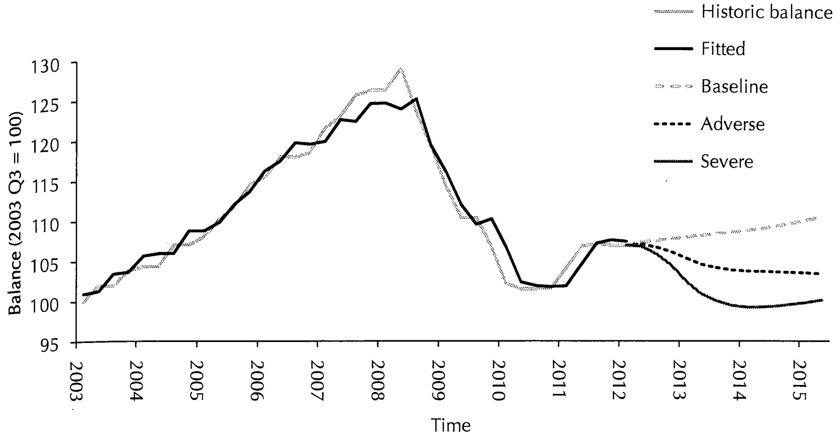
appealing as well, and not in the spirit of the exercise if the model is applied to, say, interest income.

In such cases, it may be most natural to overlay the projections onto the organisation's annual operating plan (that accounts for strategic initiatives) so that the augmented model has baseline projections that align with the operating plan. An example is scaling projections by the ratio of the institution's operating plan growth rate and the model's unadulterated baseline projection. This will result in changes to the dispersion across the three scenarios. For example, if the organisation's baseline is greater than the modelled baseline, projections under the Federal Reserve scenarios will be scaled up and dispersion will be greater than that implied by the unadulterated model. Alternatively, one can shift projections by the difference between the institution's operating plan growth rate and the model's unadulterated baseline projection, keeping the dispersion in projection unchanged.

Figure 12.5 provides an example of such an overlay. One can see the muted growth under the baseline and the, perhaps more realistic, adverse scenario.

The choice of overlay should depend upon the extent to which the organisation believes scaling or shifting best reflects the dynamics in

Figure 12.5 C&I balance levels (June 2003=100), fitted balance from balance growth model and balance projections based on Federal Reserve 2013 baseline, adverse and severe scenarios, after adjusting for strategic overlay



the projections; backtesting may allow one to understand the most appropriate approach.

In addition, the organisation may have a view on the strategic actions it plans to take under the various scenarios that do not conform to historical patterns. In these situations, it may make sense to further adjust projections. One approach is for the organisation to quantify historical strategic decisions. While this is involved, in that it requires heavy input from the lines of business, it can provide a more precise and dynamic quantification mechanism for strategic overlays. Given that the process of bringing in strategic plans is both a quantitative and qualitative exercise, a narrative is needed to explain discrepancies and any resulting adjustments.

RECAP AND A GLIMPSE OF THE FUTURE

PPNR covers a variety of disparate items, with modelling that relies on a wide range of datasets with differing statistical properties. While disparate, there are a few points that are relevant for all PPNR line items.

First, the organisation must understand what data options (internal and external) are available and how these options align with the organisational structure so that the relevant stakeholders can be identified. Second, with data options in hand, the segmentation and categorisation of FR Y-14A line items need to be determined. This will be undertaken in conjunction with designing modelling specification and macroeconomic variable selection. Statistical analysis, along with validation, will ensure a robust statistical methodology (or at least a methodology that is superior to practical alternatives). Third, it is necessary to demonstrate that the quantitative model is appropriate for CCAR projections. The organisation must, at some level, reconcile strategic plans and the quantitative model when submitting the final projections.

With these points in mind, we should recognise that PPNR modelling is in its infancy. Institutions have only just begun to explore datasets and modelling approaches. The collection and reporting of FR Y-14Q data, for example, will eventually produce time series sufficiently long enough to allow institutions to more accurately describe PPNR line items. While peer models will likely be used for many items that have volatile dynamics resulting from idiosyncratic events, the lengthier FR Y-14Q time series will certainly provide more options. In addition, there will likely be demand for data consortiums where granular anonymised data are collected, similar in spirit to loan-level datasets such as the CRD, that will allow for much more accurate modelling.

Beyond the modelling, there is the question of application. Once sufficient data are available, and the organisation is able to develop models of sufficient accuracy, model use should move toward strategic decision-making. The organisation will be able to measure the extent to which various activities consume CCAR capital. While some organisations are beginning to recognise this variability when stress testing loan portfolios, they have not yet fully integrated this thinking when considering the application of PPNR models.

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1 See Federal Reserve Board, 2013, "Capital Planning at Large Bank Holding Companies: Supervisory Expectations and Range of Current Practice", August; Federal Reserve Board, 2013, "Dodd–Frank Act Stress Test 2013: Supervisory Stress Test Methodology and Results", March.

2 See Federal Reserve Board, 2013, "Comprehensive Capital Analysis and Review 2014 Summary Instructions and Guidance", November 1.

3 See Federal Reserve Board, 2013, "Capital Planning at Large Bank Holding Companies: Supervisory Expectations and Range of Current Practice", August.

4 For an example of a model that allows one to describe loan prepayment dynamics, see the discussion of a lattice model in Amnon Levy, 2013, "An Overview of Modeling Credit Portfolios", June, Moody's Analytics, available at: http://www.moodysanalytics.com/Insight/Quantitative-Research/Portfolio-Modeling.aspx.

5 For further details around the CRD, as well as studies that leverage the data, see http://www.moodysanalytics.com/Insight/Quantitative-Research/Default-and-Recovery/Middle-Market-Risk-Report.aspx.

6 See Federal Reserve Board, 2013, "Capital Planning at Large Bank Holding Companies: Supervisory Expectations and Range of Current Practice", August; Federal Reserve Board, 2013, "Dodd–Frank Act Stress Test 2013: Supervisory Stress Test Methodology and Results", March.

7 See, for example, Francisco Covas, Ben Rump and Egon Zakrajsek, 2012, "Stress-Testing US Bank Holding Companies: A Dynamic Quantile Regression Approach", September 24.

8 Jose M. Berrospide, Ralf R. Meisenzahl and Briana D. Sullivan, 2012, "Credit Line Use and Availability in the Financial Crisis: The Importance of Hedging", Finance and Economics Discussion Series, Divisions of Research & Statistics and Monetary Affairs, Federal Reserve Board, April 17, available at http://www.federalreserve.gov/pubs/feds/2012/201227/201227pap.pdf.

9 The historic FR Y-9C and call report datasets do not account for mergers and acquisitions. Therefore, certain banks and BHCs may see random jumps in historical segment values that are not immediately explainable and need to be corrected. The first step in correcting the historical time series for mergers and acquisitions is to examine the bank and BHC merger data. The merger and acquisition database files produced by the Federal Reserve identify mergers and acquisitions for banks and BHCs from 1976 onwards (see Chicago Federal Reserve, "Bank Merger Data", available at http://www.chicagofed.org/webpages/publications/financial_institution_reports/merger_data.cfm; and "BHC Merger Data", available at http://www.chicagofed.org/webpages/publications/financial_institution_reports/merger_data.cfm).

10 See Federal Reserve Board, 2013, "Dodd–Frank Act Stress Test 2013: Supervisory Stress Test Methodology and Results", March.

11 Ibid.

12 In some cases, it makes sense to account for non-linear and cross-effects related to projections. For example, cross-model error terms may be correlated, resulting in an augmentation to the expected value of the projection.

13 See Vishal Mangla, 2013, "Treasuries and Bank Deposits", Moody's Analytics white paper, October 11, available at http://www.moodysanalytics.com/~/media/Insight/Quantitative-Research/Enterprise-Risk-Modeling/2013/2013–03–10-Treasuries-and-Bank-Deposits.ashx.

13

Banks' Governance and Controls over Internal Capital Adequacy Processes

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Among the integral elements of an institution's internal process for assessing its capital adequacy, also known as the capital adequacy process (CAP), are the governance and controls over that process.[1] Comprehensive and sound governance and controls are vital to ensure that an institution's CAP is functioning as it should, and that decisions regarding capital adequacy are made in a rigorous manner.[2] This includes the ability of the CAP, at large US banking organisations, to meet the requirements of the Federal Reserve's Capital Plan Rule and annual Comprehensive Capital Analysis and Review (CCAR) exercise.

Together, an institution's board and senior management should establish a comprehensive, integrated and effective CAP that fits into the broader risk management of the institution. This chapter will discuss the key elements of the governance over a CAP, such as:

- strong board and senior management oversight, including periodic review of the institution's risk infrastructure, and loss and resource estimation methodologies;
- evaluation of capital goals;
- assessment of the appropriateness of stress scenarios considered;[3]
- regular review of any limitations and uncertainties in all aspects of the CAP; and
- approval of capital decisions.

The chapter will also outline the sound internal controls that help govern an institution's CAP, and help ensure the integrity of the CAP and its results, including:

☐ policies and procedures;
☐ change controls;
☐ model validation and independent review;
☐ comprehensive documentation; and
☐ review by internal audit.

BOARD OF DIRECTORS

The board of directors has ultimate oversight responsibility and accountability for the entire CAP. It should be responsible for key strategies and decisions, define the culture of the organisation and set the "tone at the top". The board is ultimately responsible for the institution's CAP, even if the board is not intimately involved in the details.

The board of directors should make informed decisions on capital adequacy for the organisation, and not just ratify recommendations made by senior management. The board of directors should receive sufficient information to understand the institution's material risks and exposures, and to inform and support its decisions on capital adequacy and capital planning. The board should receive this information at least quarterly, or when there are developments that affect capital adequacy or the manner in which it is assessed (such as major CAP methodology changes).

Capital adequacy information provided to the board should include capital measures under current circumstances, as well as on a post-stress, *pro forma* basis, and should be framed against the capital goals established by the institution taking into account obligations to external stakeholders. The board should receive clearly developed *pro forma* financial results and trend analysis, with sufficient granularity on key entities, lines of business or portfolios, as appropriate. It should also see the impact of loss and resource estimates on the existing and prospective capital positions for both expected or "baseline" conditions and stressful ones. Additionally, the board should receive an analysis explaining the differences in results between baseline and stressful conditions for all key capital measures.

Board members should have a clear and detailed understanding of the institution's capital policy, including knowledge of the institution's capital goals and the need to maintain certain capital levels to satisfy key stakeholders. The board should approve the capital policy and review it on at least an annual basis.

In its review of capital information, the board should determine whether the stressful conditions applied in the CAP, including scenarios, are current, sufficiently severe and relevant to the organisation's risk profile and business activities. In addition, the information provided to the board should include a discussion of key limitations, assumptions and uncertainties within the CAP, so that the board is fully informed of any key weaknesses in the process and can effectively challenge reported results before making capital decisions. The board should also receive summary information about mitigation strategies to address key limitations and take action when weaknesses in the CAP are identified, applying additional caution and conservatism as needed.

Institutions with better practices in this area have boards that fully understand the risks, exposures, activities and vulnerabilities that affect the institution's capital adequacy. They also understand the major sources of loss and revenue changes in the CAP, and the major drivers of changes in capital positions and ratios. Strong boards challenge information provided by senior management by asking key questions, drilling down into certain areas and/or requesting additional information. For example, boards that have evidenced more engagement in the CAP have asked specific questions around loss forecasts for high-risk/run-off portfolios, new product portfolios, a stress scenario's impact on business strategy/growth initiatives and other aspects of the *pro forma* capital analysis that are more heavily reliant on underlying management assumptions. Importantly, they recognise that CAP results are estimates and should be viewed as part of a range of possible results. Another good practice is for the board to receive information about past CAP performance. Effective boards also discuss identified weaknesses in the CAP, whether they need to take immediate action to address those weaknesses and whether the weaknesses are material enough to alter their view of current CAP results. They also discuss whether a sufficient range of potential stress events and conditions has been considered in assessing capital adequacy, including idiosyncratic events and outcomes.

Institutions should provide quantitative reports to the board that include cogent summaries, as well as underlying detail that is easily accessible. Reports should also include information about the validation and independent review of models and other quantitative tools that produce results, especially if they have identified limitations, shortcomings and uncertainties. Institutions should provide a full list of assumptions underpinning CAP results and a discussion of the impact if those assumptions do not hold. In addition, strong boards review summary reports from internal audit to ensure that all identified issues are incorporated into board discussions.

A key concern is when the board does not challenge results and information, accepts whatever is provided to it by senior management, and provides only a cursory review and challenge of management recommendations. It is also concerning when there is evidence that board members are not fully aware of – or knowledgeable about – risks, exposures, activities and vulnerabilities, or do not have a good understanding of how loss and resource estimates are generated. Some boards may not have an understanding of the capital policy, are unaware of stakeholder expectations regarding capital adequacy or simply look at minimum ratios to gain comfort with post-stress outcomes – practices that are not acceptable. Another concern is when boards make little attempt to look at past CAP performance and help determine how the CAP functions over time.

One of the most concerning shortcomings is when capital distribution recommendations do not include all relevant information, such as sufficiently stressful conditions the institution might face, and appear optimistic. In some cases, key assumptions that underpin the CAP are not specifically identified, challenged and analysed. In other cases, board members do not receive information about governance and controls over the CAP, and do not ask questions about how CAP processes ensure that reliable and credible results are produced.

SENIOR MANAGEMENT

Senior management is responsible for ensuring that CAP activities authorised by the board are implemented in a satisfactory manner, and is accountable to the board for the effectiveness of those activities. Senior management should ensure that the CAP as a whole functions effectively. In doing so, senior management is also responsible for all the CAP control functions described below, and for ensuring that the CAP contains appropriately stressful conditions for assessing capital adequacy. This includes ensuring that scenarios of sufficient stress are included, and that those scenarios together cover all material risks and vulnerabilities facing the institution.

Using appropriate information, senior management should make informed recommendations to the board of directors about the institution's capital, including capital goals and distribution decisions. Senior management should ensure that proposed capital goals have sufficient analytical support and fully reflect the expectations of key stakeholders. The capital policy should provide a clear indication of how the institution aligns with stated capital goals on a post-stress basis and an explanation of management's proposed remedial actions if those goals are not met. Senior management should identify all weaknesses in the CAP, as well as key assumptions, limitations and uncertainties, and evaluate them for materiality (both individually and collectively). It should also have remediation plans for any weaknesses affecting CAP reliability or results.

At institutions with better practices, senior management maintains an ongoing assessment of all CAP areas, identifying and clearly documenting any weaknesses, assumptions, limitations and uncertainties, and does not consider a "one-time" assessment of the CAP to be sufficient. Management considers all quantitative and qualitative information about the CAP, including reports from internal audit, and looks across all areas to determine if there are any combined/correlated weaknesses. Management has very clear remediation plans for identified weaknesses, with specific timelines. In some cases, based on its review of the full CAP, senior management makes more cautious or conservative adjustments to CAP results or recommends more cautious or conservative capital decisions.

Also of value is when senior management expresses some sense of "humility" about its ability to predict future outcomes, conveys "information scepticism" and recognises the prevalence of uncertainty. In some cases, management adjusts its recommendations to the board – including for capital actions – based on identified weaknesses and uncertainties. Senior management also includes key CAP assumptions, weaknesses and uncertainties in reports and specifically points them out to the board.

Of concern is when senior management does not conduct a holistic review of the CAP and/or does not have a full understanding of key assumptions, limitations, weaknesses and uncertainties. In some cases, senior management ignores identified issues, such as audit findings related to the CAP. In other cases, senior management has incomplete, poorly developed or outdated remediation plans to address identified weaknesses.

DOCUMENTING DECISIONS

An institution should appropriately document the key decisions about capital adequacy – including capital actions – made by the board of directors and senior management, and describe the information used to make those decisions. The decisions should be appropriately codified, formally approved and retained for future reference and decision-making. Having a formal documentation process for capital decisions not only provides transparency about, and a history of, decisions made, but also creates additional discipline for decision-making.

Better practices in this area include board minutes that describe clearly how decisions are made and what information was used. In addition, there should be evidence that the board exercised an appropriate challenge of results and recommendations, including asking critical questions of senior management or reviewing information indicating that senior management has asked itself those questions. This can include having the board review key assumptions and process weaknesses and, in some cases, reviewing analysis showing the sensitivity of capital to alternative outcomes. On the whole, there should be evidence that sufficient information was considered for decision-making at all levels.

Weaker practices in this area include when board minutes are very brief and opaque, with little reference to information used by the board to make its decisions. Another area of concern is when the board appears to be affirming past decisions without any new analysis. It is also problematic when senior management recommendations are difficult to understand or do not have any supporting information.

SCOPE OF INTERNAL CONTROLS

An institution's internal control framework should encompass the entire CAP, including the risk measurement and management systems used to produce input data, the models and other techniques used to generate loss and resource estimates, the process for making capital adequacy decisions and the aggregation and reporting framework used to produce management and board reporting. While institutions naturally may develop components of their CAP along separate lines, the control framework should ensure that the separate components come together in a coherent manner. Overall, the set of control functions in place should provide confirmation that all aspects of the CAP are functioning as intended.

Better practices in this area involve viewing the CAP controls on an integrated basis and ensuring they are applied consistently. These controls are viewed as a strong "second line of defence" to ensure the CAP functions effectively. Management should respond quickly and effectively to any issues identified by CAP controls and devote appropriate resources to continually ensure controls are functioning effectively. Management should also foster a culture in which control staff is accorded sufficient stature, authority and respect within the entire organisation. In addition, institutions with better CAP controls ensure that they are used in key process flows and at key decision points in the CAP, demonstrating that they understand where controls are needed most (such as to avoid potential conflicts of interest or to ensure effective challenge).

In some cases, solid controls exist in certain areas but are not consistent on a holistic basis. For example, there may be sound controls in given business lines, but not in others. Some institutions might incorrectly view controls as more of an afterthought or a compliance exercise just to satisfy supervisors; this approach is often evidenced by the lack of stature of control staff in the organisation. In certain cases, management is not fully aware of control lapses or devotes little attention to ensuring that controls are sound. A major concern is when key control lapses have been unaddressed for some time or occur in fundamental areas, such as capital decision-making.

POLICIES AND PROCEDURES

Institutions should ensure they have policies and procedures covering the entire CAP, including a specific capital policy. Policies and procedures should ensure a consistent and repeatable process for all components of the CAP, and provide transparency to third parties for their understanding of an institution's CAP processes and practices. Policies and procedures should be comprehensive, relevant to their use in the CAP and periodically updated and approved. Policies and procedures should include sufficient detail for each aspect of the CAP. There should also be evidence that management and staff are adhering to policies and procedures in practice, and there should be a formal process for any policy exceptions. Such exceptions should be rare and approved appropriately. Policies should be reviewed and updated at least annually, and more frequently when warranted.

Institutions should have a specific capital policy containing guidelines used for capital planning, capital issuance, and usage and distributions. A capital policy should include: internal capital goals; quantitative or qualitative guidelines for dividends and stock repurchases; strategies for addressing potential capital shortfalls; and internal governance procedures around capital policy principles and guidelines. It should be a distinct, comprehensive written document that addresses the major components of the institution's capital planning processes, and links to – and is supported by – other policies (risk management, stress testing, model governance, audit, etc). A capital policy should provide details on how an institution manages, monitors and makes decisions regarding all aspects of capital planning.

A capital policy should also describe targets for the level and composition of capital, and provide clarity about the institution's objectives in managing its capital position. The policy should explain how the institution's capital planning practices align with the imperative of maintaining a strong capital position and being able to continue to operate through periods of severe stress. It should also specify the capital metrics that senior management and the board use to make capital decisions. In addition, a capital policy should include governance and escalation protocols that are clear, credible and actionable in the event an actual or projected capital ratio target or capital level target is breached. In addition to an annual review of policy by the board, institutions should establish a minimum frequency (at least annually) and other triggers for when its capital policy is reevaluated, and ensure that these triggers remain relevant and current.

Better practices for policies and procedures are when they are clearly an integral part of sound risk management and capital planning. Institutions ensure that policies are clear and comprehensive, allowing a third party to gain a good sense of how actions are carried out. It is also important to see that CAP policies and procedures are followed in practice – for example, institutions with better practices make reference to policies when making decisions and taking actions, have established protocol for making policy exceptions and exhibit few variances with policy.

Weaknesses in policies and procedures can include insufficient coverage or lack of detail. In other cases, policies do not clearly outline roles and responsibilities of groups or individuals involved in a given process. Concerns arise when policies lag or are inconsistent with practice, or when policies are violated with no protocol for approval. Both issues raise concerns that the policies are written just as compliance exercises and are not serving as governing documents. Other concerns are when policies and procedures are developed or applied inconsistently across the CAP – ie, that some areas are determined to be more important that others, or some policies are inconsistent or even contradict one another.

ENSURING INTEGRITY OF RESULTS AND CHANGE CONTROLS

Specific to the CAP, an institution should have internal controls that ensure the integrity of reported results and the documentation, review and approval of all material changes to the CAP and its components. An institution should ensure that change controls exist at all levels of the CAP.

An institution should have controls to ensure that management information systems (MIS) are robust enough to support analysis for the CAP, with sufficient flexibility to run *ad hoc* analysis as needed. Furthermore, an institution should have specific reconciliation and data integrity processes related to key capital adequacy reports. An institution should have an established process for presentation of aggregate, enterprise-wide results, describing any adjustments made in the aggregation process. There should also be an objective party to ensure that reports provided to senior management and the board contain the appropriate level of detail, and are accurate and timely. The review should also assess whether the institution complies with its internal capital targets/guidelines, and check whether the rationale for any deviations from stated capital objectives (either significant excesses or shortfalls) are clearly documented and approved. The different review procedures referenced above can be conducted with different frequency, subject to such considerations as the institution's internal audit cycle, the CAP reporting frequency, timing of capital plan development and updates, etc. At a minimum, however, key elements of the CAP should be subject to quality assurance assessments no less than annually.

Ensuring that good information flows exist to support good decisions, with clear investment in controls for data and information, is a leading practice in this area. For example, some institutions have an unbiased, internal party not involved in developing projections check the numbers for accuracy, and ensure formally reported numbers are given extra scrutiny and cross-checking. In addition, institutions with better practices have strong MIS in place across the CAP to be able to collect, synthesise, analyse and deliver information quickly and efficiently. These systems also have the ability to run *ad hoc* analysis as needed in one or two days without employing substantial resources.

Strong change controls include a variety of activities covering different elements of the CAP. Examples are access and editor controls over risk models used in the development of capital adequacy analysis (eg, loss and resource estimation models), maintenance of the CAP policy environment to ensure that roles and responsibilities reflected in key policies are consistent with the institution's practices, and standards related to the level of support and management sign-off required to breach limits or deviate from stated policies and processes. Strong change controls are vital to the maintenance of an appropriately formal and repeatable process over time, allowing for process improvements to be integrated into the CAP, defining the bounds of management discretion and ensuring a transparent audit trail with respect to material process changes.

Some institutions exhibit a strong "culture of information", as all staff recognise the importance of data and the need to keep it up-to-date. Further, all information presented is effectively challenged by appropriate parties within the organisation. All estimates and projections are recognised as such, and information about uncertainty associated with those estimates and projection is presented to users so they can question and challenge where necessary.

Performance of the CAP can be inhibited by slow, antiquated and/or inaccurate MIS. Of most concern are cases in which data corrections indicate that management may have made different decisions in the past if they had accurate data. In other cases, MIS might be siloed and different systems are not fully compatible, require substantial human intervention to reconcile or require extensive time to produce meaningful and reliable information.

VALIDATION AND INDEPENDENT REVIEW

An institution should conduct validation and independent review of all models used in the CAP, consistent with existing supervisory expectations on model risk management.[4] Models should be independently validated or otherwise reviewed by unbiased parties. The validation and review process should include: (i) an evaluation of conceptual soundness, including supporting developmental evidence; (ii) an ongoing monitoring process that includes verification of processes and benchmarking; and (iii) an outcomes analysis process that includes backtesting (as appropriate for the different models used within the CAP). An institution should ensure that there is effective challenge with respect to the evaluation of all key models used within the CAP. Validation staff should have the necessary technical competencies, sufficient stature within the organisation and appropriate structural and/or functional independence.

An institution should maintain an inventory of all models used in the CAP, including all input or feeder models. Higher-risk and higher-impact models should receive additional attention, and be subject to more frequent validation and review. Consideration should be given to the use of models under stressed conditions if models were developed originally for use under baseline economic/financial environments. There should also be a process to incorporate compensating controls if model weaknesses and uncertainties are identified.

Many institutions maintain an updated inventory of all models used in the CAP based on a clear definition of what constitutes a model. Institutions with better practices ensure that models have been validated for their intended use, such as a model designed for business-as-usual modified to be used for stress testing. Such institutions are also transparent about the validation status of all CAP models, and appropriately address any models that have not been validated or have identified issues by restricting model use, putting compensating controls in place, or using benchmark or challenger models to help confirm the output of the primary model. Institutions with better practices acknowledge shortcomings in model risk management and have plans in place to remediate those quickly.

Nearly all institutions continue to face challenges in conducting outcomes analysis of their CAP stress-testing models given limited realised outcomes against which to assess projections. However, some institutions do not attempt to compensate for challenges in outcomes analysis by conducting additional sensitivity analysis or other types of validation work. Other common deficiencies include failure to validate some models used in the CAP (including some high-impact stress-testing models), treating the output from models that have not been validated the same as the output from validated models, and lack of effective challenge by validation staff. In certain cases, institutions are not able to identify all models used in the CAP or scoped some models out of validation. In other cases, institutions rush validation work, even though work may not be complete or rigorous. Additionally, validation does not always cover management overlays or judgemental adjustments to model output. The challenge process can be ineffective at some institutions because those validating or reviewing models have conflicts or are not unbiased. Another shortcoming is when validators do not have sufficient technical expertise or familiarity with business lines or the intended use of models.

DOCUMENTATION

An institution should have clear and comprehensive documentation for all aspects of its CAP, including its risk measurement and management infrastructure, loss- and resource-estimation methodologies, the process for making capital decisions, and efficacy of control and governance functions. Documentation should contain sufficient detail, accurately describe the institution's practices, allow for review and challenge and provide relevant information to decision-makers.

Comprehensive and clear documentation is an important but often overlooked aspect of the CAP. Institutions should ensure that all areas of the CAP are documented and establish standards for detailed, comprehensive and current documentation. For instance, an institution might establish minimum documentation expectations that must be met before validation or key decisions can occur. Greater emphasis on documentation can also help ensure that proper change controls are in effect. Better documentation includes non-technical executive summaries for longer documents. Institutions should ensure that they are provided with thorough documentation from vendors or other external parties.

Key red flags for documentation include logic, math or egregious typographical mistakes, as well as outdated references. Concerns also arise when institutions' validation or audit staff has not been able to understand how a given CAP practice or process functions based on the documentation provided.

INTERNAL AUDIT

Internal audit should play a strong role in evaluating the CAP and its components. A review of the full CAP, not just the individual components, should be performed by audit periodically to ensure that the entire end-to-end process is functioning as expected and in accordance with the institution's policies and procedures. Reviews by audit should have sufficient scope, frequency and depth, covering all material aspects of the CAP. Audit staff should have the appropriate incentives, competence and influence to identify and escalate key issues. Internal audit should review the manner in which CAP deficiencies are identified, tracked and remediated. Audit should report regularly on the status of the CAP to senior management and the board, presenting key findings as needed. An institution should have a process for addressing audit concerns in a timely manner.

Institutions with better practices place strong emphasis on having high-quality internal audit involvement in the CAP by providing a comprehensive, robust review of all the CAP components in some depth, including all the control areas discussed above (eg, model risk management, change controls and compliance with policy). Institutions with strong internal audit for the CAP have strong issue identification and remediation tracking. They also ensure that audit has strong technical expertise, strong stature in the organisation and proper independence.

Lagging practices include incomplete audit coverage of the CAP or the use of cursory or high-level reviews for some areas. Other weak practices include when internal audit provides few or superficial findings and does not follow up to ensure issues are remediated. In other cases, senior management does not pay full attention to audit findings or is slow in addressing them. Another cause for concern is when supervisors uncover key issues that audit has missed in its review.

Importantly, institutions should recognise that internal controls are not just a bureaucratic "checklist", but rather constitute an integral and dynamic element of sound risk management and capital planning. For example, institutions should conduct an end-to-end review of the CAP in series, not just as one single event that tries to capture everything at one time to simply "tick the box." Senior management should evaluate the end-to-end assessments of the CAP, ask specific questions about its elements and respond to any findings from the assessments. Further, the board should be briefed on the end-to-end assessments, with any key issues brought to their attention.

CONCLUSION

This chapter has described the sound governance and controls to support an institution's CAP. Governance and controls over a CAP are especially important given the breadth and depth of practices, processes, and issues covered in the CAP. These include strong oversight of the entire process and comprehensive internal controls at every step. While some practices described in the chapter may appear more mundane and less "interesting" than other aspects of capital planning, without them a CAP's results will not be reliable and credible. In fact, an important contributor to sound capital planning is paying attention to key details that to some might seem irrelevant, but are in fact very important. Among other things, these can include comprehensive policies and procedures, rigorous model validation, detailed documentation and strong change controls. By focusing on these and other important details, institutions can provide a strong foundation and infrastructure that helps produce credible, relevant, reliable and consistent CAP results.

[1] The expectations articulated in this chapter relate to large banking organisations. For a more comprehensive discussion of US supervisory expectations and the range of practices for capital planning at large banking organisations, see "Capital Planning at Large Bank Holding Companies: Supervisory Expectations and Range of Current Practice, August 2013", available at http://www.federalreserve.gov/bankinforeg/bcreg20130819a1.pdf.

2 It is important to note that the capital adequacy process described in this chapter is equivalent to an internal capital adequacy assessment process (ICAAP) under Pillar 2 of Basel II. Accordingly, the expectations articulated here relating to the CAP are essentially the same as for the ICAAP.

3 For information on governance over stress testing used in capital planning, see David Palmer "Governance over Stress Testing" in Akhtar Siddique and Iftekhar Hasan (Eds), 2013, *Stress Testing: Approaches, Applications and Methodologies* (London: Risk Books), pp 1–14.

4 See "Guidance on Model Risk Management," Federal Reserve SR 11–7, April 4, 2011, available at http://www.federalreserve.gov/bankinforeg/srletters/sr1107a1.pdf.

14

CCAR and Capital Management: Relationship with Economic Capital, Regulatory Capital and ICAAP

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In the post-financial crisis world, capital planning and capital management have taken an ever-increasing prominence, not only from the regulators' point of view but also internally as large banks in the US have dedicated more resources and attention to capital adequacy. The Federal Reserve's Capital Plan Rule[1] and the Comprehensive Capital Analysis and Review (CCAR, the Federal Reserve's supervisory programme for assessing large banks' capital plans and capital adequacy processes) have emerged as the most important capital assessment programmes being implemented and continuously enhanced.

While the focus has been on CCAR, other similar capital management initiatives of varying degrees of maturity have already been implemented at large banks. Examples include regulatory capital and Basel-driven initiatives (including Basel I, II, II.5 and III) and banks' internal views of risk-based capital requirements primarily driven by economic capital programmes. As banks continue to enhance and evolve these programmes, it is important to understand the context, objectives and applications of each, as well as the relationships among them and how they can be leveraged in support of one another. A comprehensive awareness of these initiatives will help banks streamline internal processes around their overall capital management programme, establish appropriate governance, management oversight and attention, and provide clarity across different levels of bank management, including the board. Furthermore, as banks go through additional regulatory-driven initiatives, this understanding can help to optimise resource allocation.

The objective of this chapter will be to provide an overview of the different capital management initiatives that exist within the large banks in addition to CCAR, and to provide a detailed comparison that includes the potential synergies that may exist across these initiatives. The first part of this chapter will describe the evolution of capital management practices and related capital management initiatives within a typical large bank. Following this, there is a detailed comparison across relevant capital management initiatives from two different lenses: modelling approaches, and governance and processes. How all these different capital management practices and initiatives should be leveraged in an integrated manner for different capital management applications is then explored. The chapter continues with a description of the key capital management applications, including capital limits and targets setting, capital adequacy assessment and risk-adjusted performance evaluation and capital optimisation. Finally, some insights around how banks should go about implementing a target state comprehensive capital management framework that incorporates all of these capital initiatives (including CCAR) are offered.

EVOLUTION OF CAPITAL MANAGEMENT PRACTICES

Capital management practices have evolved since the introduction of the concept of risk-adjusted return on capital (RAROC) by Bankers Trust in the 1970s and the first Basel Accord in July 1988 (Basel I). The latter established the concept of risk-based minimum capital requirements that banks should maintain to remain solvent. Although Basel I was aimed at establishing risk-based capital management practices, it was limited by a lack of adequate risk coverage granularity. As industry participants realised its limitations, and as computational capabilities increased, banks developed more advanced internal risk measurement approaches through economic capital methodologies. This led to heavy investment in systems designed to measure risk associated with the different business lines and increasingly diverse financial products that were developed during the 1980s and 1990s due to financial deregulation.

The evolution of economic capital methodologies allowed for more refined measures and granular estimates of capital. In light of the limitations of Basel I, increased computational capabilities and the banks' efforts to develop more advanced internal approaches, the Basel Committee of Banking Supervision (BCBS) proposed the Basel II Accord (Basel II) to closely reflect the set of industry practices that had been developed by the private sector through measures such as economic capital.

Prior to Basel II, capital management concentrated primarily on risk-based capital calculations. Basel II expanded the focus of capital management practices to include the capital adequacy assessment process, as well as reporting and external disclosures. Basel II was based on three pillars, the first of which introduced a more risk-sensitive approach to measuring credit risk that allowed banks to use their own parameters in capital estimation, and defined requirements for operational risk capital. The second pillar established a framework for the assessment of capital adequacy through the Internal Capital Adequacy Assessment Process (ICAAP) that could be used as an additional supervisory tool. The third pillar formalised disclosure requirements aimed at reinforcing market discipline.

Even with these enhancements, Basel II fell short with respect to adequate risk coverage and granularity. The financial crisis of 2007–08 revealed its limitations and led to the development of the Basel III Accord (Basel III) in 2010. Basel III provided a stricter definition of regulatory capital, increased the scope and level of risk-weighted assets (RWAs), increased minimum capital requirements and introduced new liquidity requirements. Additionally, in response to the limitations associated with regulatory measures of trading and securitisation positions, the BCBS released revisions known as Basel II.5 as an interim measure. Basel II.5 sought to increase the risk sensitivity and conservatism of capital requirements related to market risk.

Another key realisation from the financial crisis was that simulation-based statistical models and scenario projections conditioned only on historical macroeconomic data were not adequate for sound risk and capital management. Since Basel II (including ICAAP) had only been recently introduced when the financial crisis hit, banks had not made much progress in complying with the ICAAP requirements, especially requirements related to stress testing.

In response, the US banking regulators introduced the Supervisory Capital Assessment Program (SCAP) in 2009, which required the 19 largest bank holding companies (BHCs) to perform stress tests based on two scenarios provided by regulators. The purpose of the exercise was to assess whether these organisations had adequate capital to withstand the financial crisis and the impending recession. Another objective of SCAP was to assess these institutions on a relative basis under the same macroeconomic scenarios, since the individual stress tests conducted under individual bank ICAAP programmes used different scenarios and assumptions. Since SCAP was launched, stress testing has evolved into the more formal CCAR programme, with much broader scope and objectives than just credit loss forecasting.

The evolution of capital management practices, along with related capital management initiatives, is summarised in Table 14.1.

As evident from the summary, the capital management programme has evolved from looking only at risk-based capital calculations under Basel I. It has come to consist of comprehensive capital management frameworks involving not only more advanced and sophisticated modelling approaches, but also governance processes and controls. This evolution has resulted in banks focusing on various capital management activities, such as regulatory capital, economic capital and stress testing. We will now provide a high-level overview of each of these developments.

Regulatory capital (Basel I/II/II.5/III)

Regulatory capital frameworks have evolved to become more comprehensive, conservative and risk-sensitive since Basel I was issued. Basel I was primarily focused on establishing regulatory capital requirements for credit risk exposures based on broad asset categories. The 1988 accord was the first attempt by national regulators to establish a consistent approach for determining bank capital requirements across jurisdictions. The Basel I framework also established a common definition of what constituted available capital in the form of Tier 1 and Tier 2 capital, although the definition of what was to be included in the capital calculation was relatively lenient. For instance, operational risk was not included, and it was not until 1996 that the market risk amendment was issued to address the need to hold capital associated with the risk of trading activities.

Table 14.1 Evolution of capital management practices

	Regulatory capital	**Economic capital**	**CCAR and DFAST**
Overview	☐ Established by Basel accords ☐ Minimum capital requirements	☐ Initially developed as management response to lack of risk sensitivity in Basel I	☐ Scenario-specific stress test ☐ Scenarios developed by regulators and BHCs ☐ CCAR applies to all US$ 50billion+ BHCs; Dodd–Frank Wall Street Reform and Consumer Protection Act (DFA) stress test (DFAST) applies to all US$10 billion+ BHCs[2]
Application	☐ Used by regulators to establish minimum capital buffers	☐ Capital sufficiency and allocation across lines of business (LOBs)	☐ Stress losses conditioned on specific macroeconomic scenarios
Limitations	☐ Capital requirements were insufficient during 2008 financial crisis	☐ Distributions are based on historically observed data which may not accurately reflect future risk	☐ May fail to recognise stresses from non-macroeconomic events
Frequency	☐ Designed to be continuous process	☐ Designed to be continuous process	☐ Regulators provide scenarios to firms and model capital annually ☐ BHCs generate scenarios and model capital semi-annually[3] ☐ Intended to be incorporated into business-as-usual (BAU) processes
Timeline	☐ Basel I first implemented in 1988 ☐ Basel III to be fully implemented in 2019	☐ Initially developed in response to regulatory capital in the late 1980s, framework has continued to evolve	☐ Initiated in 2009 for 19 largest BHCs ☐ Stress tests of varying scope and comprehensiveness apply to BHCs with US$10 billion+ in assets

As computational capabilities advanced in the 1990s, banks developed more advanced internal risk measurement and management frameworks that made Basel I obsolete. In response, the BCBS adopted some of these practices and proposed Basel II to more closely reflect the techniques that had been developed by the private sector through measures such as economic capital. Basel II envisioned that banks would eventually migrate to developing internal credit risk models for use in estimating capital requirements, and included provisions to facilitate the transition. Basel II allowed for credit risk to be measured using one of three methods: the standardised approach, the foundation internal ratings-based approach (foundation IRB) and the advanced IRB approach.

As the name implies, the standardised approach allowed a bank to use a set of standardised risk weights to estimate their credit risk. Weights were based on asset class and either external credit rating (for securities and other exposures rated by one of the major rating agencies) or delinquency rates (for retail and non-rated commercial loans). Because these risk weights were applied to all performing loans within an asset class irrespective of the relative risk (for example, within an asset class, a performing sub-prime loan would receive the same risk weight as a performing super-prime loan), they were designed necessarily to be conservative.

However, Basel II also allowed banks to use internal data to develop models that could better differentiate credit risk within asset classes. The foundation IRB approach allowed banks to create probability of default (PD) models using internal data, while using standard estimates of loss given default (LGD), exposure at default (EAD) and asset correlation. The advanced IRB approach allowed banks to create internal estimates of all credit loss parameters. To use either approach, banks had to first establish internal data histories covering a full economic cycle (typically five to seven years of historical data).

Furthermore, regulatory approval was required for a bank to move away from the standardised approach to either the foundation or advanced IRB approaches. The timing of Basel II's implementation in the US coincided with the 2008 recession, so regulators exhibited caution in reviewing and approving foundation or advanced IRB models. Indeed, as of October 2013, no US banks were fully Basel II-compliant.

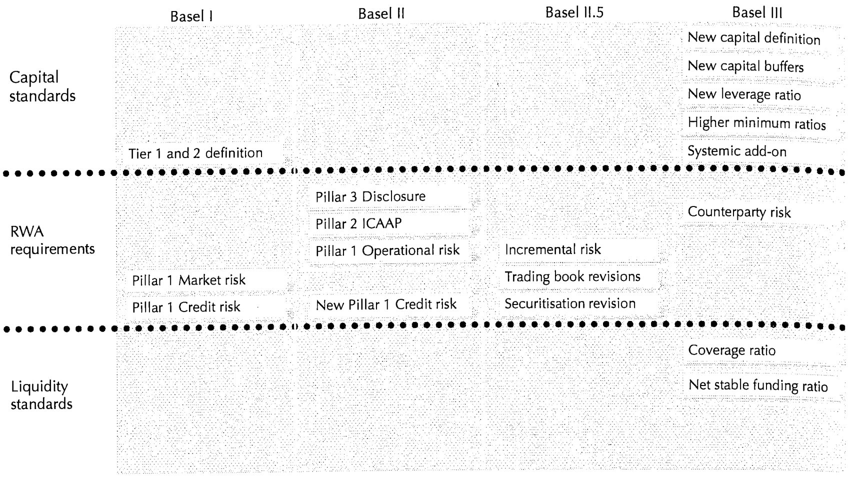
In addition to expanding the breadth of credit risk modelling options, Basel II also established operational risk as a modelling category in itself. Similar to credit risk, Basel II provided banks with the opportunity to use either prescribed weightings or to develop models using internal historical data.

The 2007–08 financial crisis revealed the limitations of Basel II and led to the development of Basel III in 2010. While Basel II did increase minimum capital requirements, its primary focus was on better quantifying credit and operational risks (through Pillar 1) and on improving the oversight and disclosure of risk (through ICAAP and Pillar 3 disclosures). Conversely, while Basel III does call for some updates to the credit risk modelling methodology (most significantly, through the use of a downturn PD instead of the through-the-cycle PD required under Basel II), its primary consequence is to provide a stricter definition of regulatory capital, increase the scope and level of RWA, increase minimum capital requirements and add new liquidity requirements. For example, Basel III places a greater importance on the Tier 1 common capital ratio by increasing the minimum capital requirement. At the same time, it modifies and limits some of the prior deductions on Tier 1 capital to emphasise the quality of capital, and introduces the concept of countercyclical capital buffers.

Additionally, to provide for the limitations identified in Basel II, prior to Basel III's formal adoption the BCBS released a revision known as Basel II.5. This revision helped account for the limitations associated with regulatory measures of trading and securitisation positions, and sought to increase the risk sensitivity and conservatism of capital requirements related to market risk. A summary of the evolution of Basel standards is shown in Figure 14.1.

As regulatory capital requirements have become more restrictive, performance measures based on RWAs and the Tier 1 common capital ratio have taken an increasing prominence in many banks' capital management and business decision-making tools. This has been at the expense of economic capital measures that had been the primary basis for risk-based performance measurement in the pre-crisis environment. The most advanced financial institutions have been implementing models and systems that can estimate and allocate RWAs at the loan and position level, allowing for their full incorporation into business decisions. In this context, RWAs are used

Figure 14.1 Incremental changes in Basel requirement



	Basel I	Basel II	Basel II.5	Basel III
Capital standards	Tier 1 and 2 definition			New capital definition New capital buffers New leverage ratio Higher minimum ratios Systemic add-on
RWA requirements	Pillar 1 Market risk Pillar 1 Credit risk	Pillar 3 Disclosure Pillar 2 ICAAP Pillar 1 Operational risk New Pillar 1 Credit risk	Incremental risk Trading book revisions Securitisation revision	Counterparty risk
Liquidity standards				Coverage ratio Net stable funding ratio

by many institutions as the common currency to evaluate performance on a risk-adjusted basis.

Economic capital

The introduction of the concept of RAROC impelled the largest global banks to develop capabilities to measure risk through economic capital methodologies. This led to heavy investment in systems designed to measure risk associated with different business lines and the increasingly diverse financial products developed during the 1980s and 1990s due to financial deregulation. As economic capital methodologies evolved, they allowed for more refined measures and more granular estimations of capital.

Unlike regulatory capital, economic capital methodologies and practices were not prescribed by the regulators, but evolved primarily as a result of the banks' own desire to increase the level of sophistication of what became the single measure of risk used for multiple management applications. Banks needed an alternative to the Basel I framework, which was insensitive to the relative risk profiles of different assets within a bank's portfolio. Basel I would, for example, assign equal capital weights to the most and least risky pass-rated loans within a commercial book, despite these assets clearly representing different levels of risk.

Until the beginning of the financial crisis in 2007–08, leading global institutions used economic capital for a number of management applications:

- satisfying regulatory requirements, including Basel II's ICAAP requirements that banks consider capital needs above the regulatory minimums (details of ICAAP are discussed in the following section);
- understanding and quantifying risk exposures;
- risk-adjusted performance measurement and reporting;
- improved risk-based pricing;
- more active portfolio management;
- more efficient capital allocation;
- better definition of risk tolerance and limits;
- improved strategic planning and budgeting; and
- better communications with credit rating agencies.

In the years before the financial crisis and up to 2010, the second tier of banks in terms of size, footprint and sophistication were still in the process of developing their economic capital frameworks with the objective of reaching a more mature state.

In the years since the financial crisis, increasing regulatory requirements – including Basel III, minimum capital requirements post-stress (eg, CCAR) and non risk-sensitive requirements such as the leverage ratio – have imposed much stricter constraints on the capital requirements of the largest banks, particularly those designated as systemically important. In light of these other requirements, which have become the *de facto* binding constraint for the vast majority of institutions, many banks have begun to measure profitability on the basis of regulatory capital. Nonetheless, economic capital can continue to inform decisions about true risk-adjusted profitability, and can spur internal management discussions when the two measures suggest different levels of risk (eg, a business may appear to be attractive from an economic capital perspective, but not based on its regulatory capital burden).

While RWAs are used by many institutions as a more relevant measure of risk than economic capital, banks have yet to develop metrics that fully incorporate the capital impact of business decisions at the business unit and deal level. Banks have developed the capability to estimate capital requirements associated with stress testing and the leverage ratio at the top of the house. However, the allocation of stress capital at the deal level for pricing purposes remains a challenge the industry needs to address.

Although the common currency for risk measurement is based on regulatory capital requirements, the principles and tools developed by banks based on economic capital will continue to serve as the basis for management applications, including capital adequacy assessment and risk-based performance measurement.

ICAAP

The second pillar of the Basel II framework, related to the supervisory review of compliance with risk-based capital requirements, specifically focuses on a review of ICAAP. While the other pillars of the advanced approaches rule emphasise risk and capital analytics, calculation methodologies and disclosures, ICAAP focuses more on processes and governance for capturing other risks that are not captured in the Pillar 1 calculation and for establishing capital adequacy assessment. This allows supervisors to assess a bank's compliance with the rule requirements, and to incorporate other types of assessments such as stress tests and reverse-to-destruction scenarios into their overall capital assessments, thereby providing a buffer over and above Pillar 1 requirements. The primary objectives of ICAAP are to ensure that:

- all the relevant risks are identified, assessed and measured;
- appropriate capital limits and targets are set that relate directly to these risks; and
- appropriate processes and governance are established that allow the supervisors to assess the integrity of ICAAP.

ICAAP can be thought of as another evolutionary step in constructing a cohesive framework that aligns risk and capital management, strategy and risk appetite into a comprehensive process and governance-driven framework.

In a way, the timing of ICAAP was also very appropriate because of the 2007–08 financial crisis, which forced banks' senior management and boards to improve their risk and capital management practices. Banks have adopted ICAAP's objectives and the Pillar 2 rules by establishing end-to-end risk and capital management frameworks that include a comprehensive set of processes covering all risk and capital management activities. Examples of industry-leading ICAAP practices include end-to-end processes through the planning, execution and evaluation phases of a bank's operating cycle, and would cover strategic planning and risk appetite setting, new business identification, risk identification and assessment, capital planning, budgeting and forecasting, risk measurement and modelling, capital evaluation and capital adequacy assessment, risk-adjusted performance evaluation and capital allocation, and integrated reporting.

Under ICAAP, the various measures used to evaluate capital adequacy include regulatory capital measures, economic capital measures and scenario-based measures. Key applications of ICAAP include alignment of risk and capital management practices, risk-appetite setting, capital allocation decision-making and capital adequacy assessment. ICAAP's association with other capital management programmes within the bank can be thought of in the following ways.

- As a leading practice, ICAAP utilises regulatory capital measures (ie, Pillar 1 minimums), economic capital measures and stress scenario-based measures as part of the risk appetite, limits setting and capital adequacy assessment processes.
- In many ways, CCAR can be thought of as aligning with ICAAP's processes, practices and goals. This is especially highlighted by the supervisory expectations document published by the Federal Reserve in August 2013, which advocates the seven principles of an effective capital adequacy process that align closely with ICAAP's requirements.[4]
- CCAR includes a set of three Federal Reserve-defined macroeconomic scenarios and two macroeconomic scenarios defined by each covered bank. Bank-defined scenarios are meant to reflect the firm's idiosyncratic risks. Similarly, ICAAP is meant to be sufficiently comprehensive as to include idiosyncratic scenarios and other considerations, such as reverse-to-destruction scenarios. In other words, ICAAP is meant to consider factors that may be outside the scope of a simple macroeconomic downturn, including low-probability but high-impact shocks or scenarios.

Stress testing: SCAP, CCAR and DFA stress testing

CCAR and DFAST are the main initiatives by US regulators originating from the financial crisis of 2007–08 that have the goal of enhancing risk and capital management practices within large banks. From the risk-based capital management point of view, one of the main realisations was that pure historical data and simulation-based statistical models were not adequate by themselves to provide sound risk and capital management, and that a scenario-based approach was required to augment the existing risk-based capital requirement calculations. Although ICAAP also recommended stress testing as part of capital adequacy, banks had not made enough progress on their stress-testing capabilities by 2008. Additionally, banks' internal stress-testing exercises performed under ICAAP were not comparable across banks because there were no prescribed, common scenarios.

US banking regulators introduced SCAP to compel the top 19 BHCs to perform stress tests based on two scenarios provided by the regulators. The purpose of the exercise was to assess whether these organisations had adequate capital to withstand a continued financial crisis and prolonged recession based on a common set of stress scenarios.

Since SCAP, supervisory stress testing has expanded beyond the original top 19 BHCs. The annual CCAR exam has come to include all domestic banks with US$50 billion or more in total assets, and any non-bank financial company designated by the Financial Stability Oversight Council (FSOC) for supervision by the Federal Reserve Board. In addition, the annual company-run DFAST applies to BHCs with US$10 billion or more in total assets, while the annual supervisory-run DFAST and mid-cycle company-run DFAST apply only to firms with US$50 billion or more in total assets.[5]

Additionally, the Federal Reserve has proposed a rule to require large, internationally active banks operating in the US to create US intermediate holding companies (IHCs).[6] Similar to US BHCs, IHCs with US$50 billion or more in total US assets would be subject to section 165 of the DFA's enhanced prudential standards, including stress testing, beginning in autumn 2015. IHCs holding US$10–50 billion in total US assets would be required to run the annual company-run DFAST.

Had banks been more proactive in implementing ICAAP programmes, it is possible that DFA may not have formalised its stress-testing requirement as a means of evaluating loss during stress scenarios. However, it is more likely that formal stress testing was the inevitable next step in the evolution of bank capital evaluation. The financial crisis highlighted the need for regulators to assess the viability of banks, stabilise the markets and measure companies on a comparable basis, and consequently generated broad support for stress testing with a common set of macroeconomic variables.

A number of changes and enhancements have ensured continuous improvement in the way banks manage their risk and capital; these changes, from the first submission in the summer of 2009 to the latest CCAR version, are summarised below.

- The initial 19 participating banks began stress testing their loan portfolios against regulatory-prescribed macroeconomic scenarios in 2009 under SCAP. This process evolved and expanded, with these largest banks performing the CCAR exercise and submitting their capital plans to regulators in early January every year since 2011. DFAST has taken on increasing levels of detail and sophistication, and is now required for all banks with at least US$10 billion in assets.
- CCAR and DFAST have become more formalised with the introduction of capital plan and stress-testing rules (see Table 14.2 for a summary of finalised regulatory requirements).
- The CCAR submissions have been formalised with submission requirements for FR Y-14 ("Capital Assessments and Stress Testing") schedules on an annual, quarterly and monthly basis; all Y-14 schedules must reconcile with FR Y-9c ("Consolidated Financial Statements for Holding Companies"). This has put additional focus on the data quality, integrity and granularity issues that were previously raised under Basel II.
- An additional scenario has been added (from baseline and adverse, to baseline, adverse and severely adverse) and the granularity of the scenarios has also increased (additional macroeconomic parameters have been added in the scenario definition, including scenario parameters for Europe and Asia, in addition to the US).
- The rigour and focus on modelling approaches and techniques have increased significantly with every round of submission.

Table 14.2 Summary of regulatory guidance related to CCAR

Regulatory guidance	Link
"Capital Plan Rule" (now codified as 12 CFR 225.8), December 2011	Federal Register notice (76 Federal Register 74631–48 [December 1, 2011]): http://www.gpo.gov/fdsys/pkg/FR-2011-12-01/pdf/2011-30665.pdf
"DFA Stress Testing Rules (Supervisory and Company-Run Stress Test Requirements for Covered Companies)", October 2012	Federal Register notice (77 Federal Register 62378–96 [October 12, 2012]): http://www.gpo.gov/fdsys/pkg/FR-2012-10-12/pdf/2012-24987.pdf
"DFA Stress Testing Rules (Annual Company-Run Stress Test Requirements for Banking Organisations With Total Consolidated Assets Over US$10 billion Other Than Covered Companies)", October 2012	Federal Register notice (77 Federal Register 62396–409 [October 12, 2012]): http://www.gpo.gov/fdsys/pkg/FR-2012-10-12/pdf/2012-24988.pdf
"Comprehensive Capital Analysis and Review 2013 Summary Instructions and Guidance", November 2012	http://www.federalreserve.gov/newsevents/press/bcreg/bcreg20121109b1.pdf
"Capital Plan Review 2013 Summary Instructions and Guidance", November 2012	http://www.federalreserve.gov/newsevents/press/bcreg/bcreg20121109b2.pdf
"2013 Supervisory Scenarios for Annual Stress Tests Required under the Dodd–Frank Act Stress Testing Rules and the Capital Plan Rule", November 2012	http://www.federalreserve.gov/newsevents/press/bcreg/bcreg20121115a1.pdf
"Dodd–Frank Act Mid-Cycle Stress Tests 2013: Summary Instructions", May 2013	http://www.federalreserve.gov/newsevents/press/bcreg/bcreg20130513a1.pdf

Additionally, the scope of financial projections and related requirements has also been enhanced significantly with a specific focus on balance-sheet and income-statement projections (pre-provision net revenue, PPNR, models) and related loss projections for each portfolio and risk type.

☐ As part of the CCAR programme, select results of the stress-testing exercise for each participating bank are publicly disclosed:
  ○ CCAR: Federal Reserve publishes Federal Reserve-modelled revenues, expenses, losses and post-stress capital ratios over the planning horizon, inclusive of the BHCs' planned capital actions, for the Federal Reserve severely adverse scenario.
  ○ Annual DFAST: Federal Reserve publishes Federal Reserve-modelled revenues, expenses, losses and post-stress capital ratios over the planning horizon, using DFAST-defined

capital distribution assumptions, for the Federal Reserve severely adverse scenario. Additionally, banks are required to publish a summary of their stress-testing methodology, incorporated risks and key internal results under the Federal Reserve's supervisory severely adverse scenario (with DFA stress testing capital actions) between March 15 and 31 each year.

  - ○ Mid-cycle DFAST: While there is no supervisory assessment for mid-cycle stress testing, banks are required to publish a summary of their stress scenario, methodology and internal results under the firm-generated severely adverse scenario (using DFAST-defined capital distribution assumptions) between September 15 and 30 each year.

- ☐ Most importantly, what started as a bank stress-test exercise has turned into a much more comprehensive risk and capital management framework, with a focus on processes and governance in addition to stress testing and quantitative modelling. The capital planning guidance from the Federal Reserve in August 2013 stressed the importance of the banks' internal capital planning and adequacy assessment processes and policies, and the supervisory assessment of these processes and policies, through a comprehensive capital management framework. It even went as far as identifying seven principles of effective capital management and capital adequacy processes, and thus formalised and reinforced CCAR by leveraging concepts first raised in ICAAP – specifically, that effective capital management extends beyond simply examining losses using a single approach (regardless of whether that approach is based on economic capital, regulatory capital or a stress test).

COMPARISON ACROSS CAPITAL MANAGEMENT INITIATIVES

As described above, capital management in large banks has been continuously evolving, and as part of that process various initiatives have been put in place – such as Basel II, II.5 and III, CCAR and DFAST, as well as economic capital initiatives that have been around for a while. In order to understand the relevance of each of these initiatives, this chapter will now provide comparisons with respect to: (i) quantitative and modelling approaches; and (ii) processes and governance. Capital initiatives relevant to the former include risk-based capital quantification under regulatory capital (ie, Pillar 1 of Basel II, Basel II.5 and Basel III), risk-based capital quantification under economic capital and risk loss projections under different CCAR and DFAST scenarios. Similarly, from the point of view of governance and processes, the relevant comparison is between ICAAP and CCAR as each of these regulatory capital initiatives expands the scope of capital management beyond risk-based calculations to focus on a broader, more comprehensive capital management framework. We will start with comparisons involving the quantitative modelling approaches.

Modelling approaches

The evolution of capital measurement requirements, from Basel I through CCAR and DFAST, also helps describe the progression of credit modelling techniques for economic and regulatory capital, and stress tests. Although there are similarities between the structure and outputs of models used to estimate capital and those used to estimate loss for CCAR and DFAST, the two forecasts are designed to help management understand and quantify risks based on different requirements.

While capital models do generate an expected loss forecast, their primary focus is on measurement and quantification of unexpected loss – that is, the potential level of loss that may only be experienced once every 10, 20 or even 100 years. Macroeconomic scenarios are incorporated into the loss estimates to the degree that model parameters are estimated based on historical data; however, the stress results output by the model are derived from the introduction of statistically induced volatility into the results (using a Monte Carlo simulation, for example). This allows users to develop a probability-weighted distribution of loss. As a result, it is not necessarily possible to link a stress forecast to a specific macroeconomic projection.

Capital forecasts are designed to estimate the short-term (12-month) PD using a "through-the-cycle" view of default – ie, default rates are effectively averaged out through the economic cycle. During relatively stressed periods, the one-year expected loss estimates produced by this method would therefore underestimate defaults, while under relatively calm periods they would overestimate defaults.

Stress-testing credit loss estimates differ from capital models in that they typically create a single path of loss. That is, regulators supply banks with a specific set of macroeconomic projections (or banks generate their own), and banks produce a single loss forecast that directly relates to the given economic scenario (rather than generating a distribution of potential loss paths, as is common in capital models). Unlike capital models that forecast total losses within one year of the forecast, CCAR models incorporate a timing element into the forecast by generating a quarterly estimate of the full balance sheet (including charge-offs, provision expense, allowance for loan loss, PPNR and loan growth) for each of the nine quarters following the forecast date.

Although it is possible to use a simulation-based model for CCAR or DFAST, it is relatively uncommon. If a simulation approach is used, regulators expect that users be still able to input a specific macroeconomic scenario into the model. However, instead of examining the distribution of outcomes, the average result across simulations is used as a credit loss estimate. A summary of the key modelling differences between frameworks is given in Table 14.3.

While economic and regulatory capital models are designed to address different objectives than stress testing, both model

Table 14.3 Capital and CCAR modelling considerations

	Economic/regulatory capital	**CCAR and DFAST**
Type	Through-the-cycle, although may include some reflection of market conditions (cycle influence) and future expectations	Point in time (time series)
Horizon	One year	Nine quarters
Loss timing	Cumulative losses projected on a quarterly basis	
Objective	Statistical distribution of loss	Stressed values
Capital actions included in forecast	None	CCAR: includes impact of dividends, stock repurchases, etc, in the BHC's capital plan DFAST: uses fixed capital distribution assumptions based on recent, historical capital actions by the BHC

frameworks offer management a means of supporting strategic decisions and can help to provide a safeguard against unexpected loss. For example, because a CCAR stress test requires a snapshot of the bank's losses and liquidity positions to be projected on a quarterly basis, it is possible to identify situations where a bank may appear to be adequately capitalised over the one-year forecast horizon generated by an economic capital model, but where liquidity constraints occur in an individual quarter of the forecast.

Similarly, the CCAR stress-loss forecast is inherently constrained in that it assumes that changes in macroeconomic variables are the primary drivers of loss, and that everything else is effectively held constant. An economic capital model can help reveal risks in the portfolio that may instead be a function of events unrelated to macroeconomic changes.

Synergies between capital and CCAR/DFAST models

Despite some of the differences in modelling techniques and requirements, many aspects of an existing economic or regulatory capital modelling process can be directly leveraged for CCAR and DFAST. Banks that have most successfully leveraged their capital frameworks for stress-testing purposes have done so across the following dimensions.

- ☐ *Data:* Perhaps the greatest synergy between the capital and CCAR/DFAST processes is through the use of clean, reconciled data. Because Basel II requires a full cycle of data for estimating PD, the same dataset that was used to estimate Basel II models can typically be leveraged for stress-testing purposes. Regulators have raised a number of concerns about the overall quality levels of data being used in models at banks of all sizes – therefore, having a clean dataset over a long time series through economic cycles can save significant time.
- ☐ *Implementation framework:* A distinct difference exists between CCAR/DFAST and capital models in that the former requires a time series of quarterly loss estimates, while the latter examine loss using a fixed one-year horizon. However, CCAR/DFAST models can leverage many aspects of the underlying capital models, such as the internal ratings, historical transition matrices used in deriving estimates of through-the-cycle PDs or the cali-

bration mechanisms designed to translate through-the-cycle PDs into point-in-time PDs.

- ☐ *Benchmarking:* Even if capital models are not used directly in CCAR or DFAST, they can serve as confirmation to give management additional confidence as to the reliability of their stress scenario results. However, it is important to exercise caution given the potential difficulty of reconciling the quarterly time series of projections required by CCAR with the one-year loss horizon produced by a capital model.
- ☐ *Process timing:* Regulatory expectations are that the CCAR/DFAST process will be incorporated into BAU. Banks that have already deployed an economic capital framework have two distinct advantages here.
  - ○ LOBs will have some familiarity with economic capital projections, and may be using them to help manage their business units. This will allow them to incorporate stress loss forecasts from CCAR and DFAST as an additional data point more readily.
  - ○ Many banks have found the process of operationalising the CCAR and DFAST models and running them in the relatively condensed timeframe required by regulators to be a large burden. Those banks that have experience in deploying a set of economic capital models typically have already established a process to quickly generate, review and approve model results.

Regardless of the modelling framework employed, the credit loss forecast is of interest to regulators when they review a bank's overall CCAR and DFAST submissions. For relatively smaller, non-systemically important banks, the credit loss forecast is often the area that drives the greatest overall stress to the balance sheet. Given this level of scrutiny, it is important to ensure that all assumptions are clearly documented and logically consistent with other areas of the submission, regardless of whether loss estimates are from a stress test or from a capital estimate.

Differences between capital and CCAR/DFAST models

There are several key differences between capital models and CCAR/DFAST stress-testing modelling. A summary is provided below.

- *Horizon of loss estimates:* Economic capital models are designed to estimate PD over a one-year horizon (that is, the probability that a loan defaults within the next 12 months from the forecast date). However, CCAR and DFAST require losses to be estimated on a quarterly basis across the entire nine-quarter forecast horizon. As a result of this timing difference, it is difficult to directly leverage a capital model for stress-testing purposes.
- *Purpose of forecast:* Economic capital models are built to forecast total defaults over a one-year horizon. CCAR and DFAST are concerned with creating a full balance-sheet projection for each quarter of the forecast horizon. As a result, for CCAR and DFAST it is necessary to project the allowance requirement and provision expense in each period in addition to loss. As companies often reserve for one year of loss for consumer portfolios and as much as two or three years of losses for commercial portfolios, the CCAR and DFAST models must estimate the timing and total amount of losses in order to determine the loss provision impact on earnings in any given quarter of the forecast.
- *New volume:* Regulatory capital under Pillar 1 is based on the portfolio as it exists as of the forecast date, while CCAR and DFAST require banks to account for new volume in their loss projections. Pillar 2's ICAAP bridges this gap to the extent that it expects a bank to consider anticipated changes in exposure tied to strategic decision and economic influences, including changes related to the risk profile of new business. However, the considerations in an ICAAP framework may not always be transparent. By contrast, CCAR and DFAST require banks to account directly for a time series of new volume in their loss projections, which also requires banks to make an assumption around how new volume is incorporated – both in terms of the new volume's delinquency status/risk rating and, for loan level models, in terms of its loan attributes (eg, FICO, loan-to-value, LTV). These assumptions can be made using a combination of management judgement and historical data.
- *Macroeconomic variables:* Depending on how the capital model was specified, macroeconomic variables may or may not be directly incorporated as model inputs. This is particularly true for PD models, which Basel II requires to produce a through-the-cycle estimate of loss. Banks have addressed the through-

the-cycle requirement in different ways: some have built changes in macroeconomic variables directly into the models, and then input an "average" macroeconomic forecast to represent a through-the-cycle view; while others have estimated models using a full cycle of data and excluded any direct macroeconomic terms. In these cases, macroeconomic influences are implicit based on the historical data used to estimate the models, but estimates are not tied to specific, explicit scenarios as of the balance-sheet date. Because regulators look for direct, transparent links between macroeconomic variables and loss forecasts, banks that took the latter approach in particular will have relatively more difficulty using capital models for CCAR and DFAST.

Governance and processes

As mentioned earlier, in addition to risk-based capital, both ICAAP and CCAR[7] have focused on broader aspects of overall capital management frameworks. Although there are certain inherent differences between ICAAP and CCAR, there are many themes common between them, as illustrated in Figure 14.2 and to be described in more detail here.

While both ICAAP and CCAR are part of regulatory requirements, ICAAP is part of the Basel II Advanced Capital Framework that was finalised in 2008, while CCAR is part of the Capital Plan Rule published in 2011. In terms of applicability, while ICAAP is applicable to all banks that are required to implement the Basel II Advanced Capital Framework, CCAR was primarily initiated as an exercise that was only applicable to the 19 largest banks within the US. It has subsequently been expanded to BHCs with US$50 billion or more in assets. Perhaps the biggest difference between ICAAP and CCAR is the purpose for which each of these was established.

ICAAP was established primarily to supplement the risk-based minimum capital calculations required under Pillar 1 to ensure that all those risks that are not captured thoroughly in Pillar 1 calculations are addressed in the overall capital adequacy assessment. To that extent, the main objectives of ICAAP included identifying and measuring all material risks that a bank faces, setting and assessing internal capital adequacy goals that are directly related to these risks and establishing a comprehensive capital adequacy assessment

Figure 14.2 Comparison of governance and processes between ICAAP and CCAR

Capital management: governance and processes	**ICAAP**	**CCAR**
Key differences	• Focused on establishing sound and comprehensive capital adequacy process that goes beyond minimum risk-based capital requirements • Part of Pillar 2 of Basel II Advanced Capital Framework (2008) • Applicable to all the banks required to implement Basel II • Quarterly capital adequacy assessment expectation	• Primarily focused on the bank's capital plan that is assessed under prescribed stress scenarios • Part of Capital Plan Rule (2011) and DFA Stress Testing Rules (2012) • Applicable to US-based bank holding companies with assets of US$50 billion or more • Semi-annual stress-testing requirements
Common themes	• Comprehensive risk identification and measurement • Risk appetite and capital limits and target setting • Focus on capital plan and contingency plans • Comprehensive governance • End-to-end processes • Robust internal controls	

process that goes beyond simply measuring the risk-based minimum capital requirements. In order to address the risks that may not have been captured in the risk-based minimum capital calculations under Pillar 1, ICAAP recommends that banks rely on additional capital adequacy assessments that may include economic capital as well as stress testing.

While ICAAP was established to supplement Pillar 1 capital calculations and to establish a comprehensive capital adequacy assessment process, CCAR was established to perform a comparative assessment of the banks' capital adequacy and their ability to withstand stress under commonly defined scenarios. Moreover, CCAR assesses BHCs' financial condition, risk profile and capital adequacy on a forward-looking basis; capital plan, capital planning process and capital policies; and strategy for, and ability to comply with, Basel III capital requirements. From this point of view, the stress-testing exercise within CCAR can be thought of as one of the many different ways that banks should be evaluating their capital adequacy assessment under the ICAAP programme. Over the past three iterations, the objectives and the scope of CCAR have expanded to establish it as a broader capital management framework that focuses on foundational risk management practices, governance, capital adequacy processes and internal controls. This evolution brings CCAR and ICAAP closer towards the end-goal of establishing a comprehensive capital management programme within the banks. Accordingly, CCAR has many common themes with ICAAP, as will be discussed below.

Comprehensive risk identification and measurement

One of the most important and fundamental aspects within both ICAAP and CCAR is the necessity for a comprehensive risk identification and measurement framework. Since capital adequacy assessment is directly linked to risks for which capital needs to be provisioned, it is extremely important to identify all the risks that a bank faces as the first step. ICAAP focuses on comprehensive risk identification and assessment to ensure that all risks that are not included in or adequately addressed by Pillar 1 of risk-based capital calculation are appropriately accounted for within the overall capital adequacy assessment. ICAAP also focuses on understanding and incorporating the interdependencies among different risks in the overall capital adequacy process. Similar to ICAAP, CCAR requires a thorough identification of all the risks faced by a bank to ensure that they are appropriately addressed under stress scenarios through which the bank's capital plan and capital adequacy need to be assessed. Thus, both ICAAP and CCAR rely on a comprehensive risk identification and measurement framework and, to the extent that banks have not yet done so, they should establish a common risk identification and measurement process that feeds into both ICAAP and CCAR.

Risk appetite and capital limits and targets setting

Another integral step in both ICAAP and CCAR is to link the risk profile of a bank to its overall risk appetite, and to establish appropriate capital limits, guidelines and targets. Once all material risks are identified, such limits, guidelines and targets are required to translate those risks into a capital adequacy assessment. From an ICAAP point of view, overall capital adequacy can be assessed against these limits, guidelines and targets under different views of capital adequacy assessment. Similarly, for CCAR, such limits, guidelines and targets can be used to assess the feasibility of a bank's strategic and capital plans under a base case as well as adverse and severely adverse scenarios. Under both ICAAP and CCAR, it is extremely important to understand and define clearly the components of available capital while establishing capital limits, guidelines and targets. It is also important to clearly define the distinctions among limits, guidelines and targets. Capital limits generally are the absolute minimum that banks should meet under all conditions. The minimum risk-based capital requirements established by regulators can be used as the starting point for establishing capital limits. Capital guidelines generally are internal warning mechanisms that are established by banks to be triggered prior to a breach in limits. Finally, capital targets generally indicate the forward-looking capital position that a bank wants to maintain under the baseline operating environment. As with the risk identification and measurement process, both ICAAP and CCAR rely on risk appetite, capital limits and target-setting processes, and banks should establish a common risk-appetite and capital-limit setting framework that can be leveraged for both ICAAP and CCAR.

Focus on capital plan and contingency plan

While the development, evaluation and approval of a bank's capital plan is the primary focus under CCAR, ICAAP also establishes the need for an effective capital plan that incorporates a bank's capital objectives and planned capital actions. Under CCAR, banks are expected to use the capital plan to clearly define their strategy, link capital requirements to the strategy through financial projections, describe planned capital actions and assess capital adequacy through baseline and stressed projections. In addition to the capital plan, both ICAAP and CCAR establish the requirement for a comprehensive capital contingency plan that lays out various contingent capital actions that can be taken under stress.

Comprehensive governance

Comprehensive governance is one of the main focus areas through which the effectiveness of a capital management programme can be assessed, and ICAAP and CCAR both highlight this aspect. Specific governance expectations for both ICAAP and CCAR include:

- board and senior management oversight and involvement;
- continuous enhancement through periodic review and remediation;
- clarity of roles and responsibilities;
- appropriate committee structure for issue escalation and resolution;
- appropriate reporting at different levels; and
- policy and documentation.

Both ICAAP and CCAR recommend increased involvement by the board, not only in capital action decisions but also in the overall capital management framework. The board is required to have a very clear understanding of: the risks the bank faces; the way these risks are captured in various risk-based capital calculations (ie, within regulatory capital calculations, economic capital calculations and CCAR stress-test loss projection calculations) and their limitations; the rationale for establishing various capital limits within the risk appetite; and the overall capital management and capital adequacy assessment process. The board is also expected to conduct a periodic review of the overall capital management framework to identify weaknesses and corresponding areas of enhancements. Finally, the board needs to thoroughly understand and review all proposed capital actions prior to approving or objecting to them. It is expected that senior management will be fully involved, and committed not only to establishing a comprehensive capital management framework but also to continuously assessing and improving it. As part of implementing such a framework, senior management is expected to incorporate all regulatory expectations (ie, Basel, ICAAP and CCAR), and also to implement industry best practices that are relevant to their institution.

Another important aspect of sound capital management governance is to have clearly defined roles and responsibilities across various functions. With the advent of ICAAP and CCAR, a comprehensive capital management programme requires robust collaboration across various functions at the corporate as well as line-of-business levels, especially within risk, finance and Treasury. In order to efficiently support such collaboration, clarity of roles and responsibilities is essential. Effective organisational structure also needs to be supported by a clearly defined committee structure that allows prompt escalation and resolution of critical issues. Reporting of timely and relevant information at appropriate levels is also critical from a robust governance point of view. Finally, both ICAAP and CCAR emphasise the need for a formal, detailed capital policy that provides adequate guidance to the overall capital management programme. Such policy should include the banks' approach to establishing capital limits and guidelines, capital adequacy assessment, capital actions decision framework and capital contingency planning. Capital policy should be supported by other key policies, including risk policy, liquidity policy, stress-testing policy and model validation policy. In addition to the policies at the highest level, banks also need to implement an overall documentation architecture that consists of various types of documentation at appropriate levels. This can include policies, manuals, methodologies and detailed procedure documentation.

Banks should establish comprehensive governance structures around their capital management programmes that address all of the issues mentioned above, and support both ICAAP- and CCAR-related requirements.

Internal controls

Internal controls are another key focus area for both ICAAP and CCAR. While ICAAP emphasises the need for a robust internal controls environment from a processes and governance point of view, CCAR highlights strong internal controls around data quality and data integrity due to its specific reporting requirements. From an ICAAP perspective, banks need to maintain strong internal controls around the processes to ensure the integrity and objectivity of their capital adequacy programme. For CCAR, in addition to controls around processes and governance, it is necessary to establish strong internal controls around data quality and integrity, as well as modelling and quantification. As mentioned earlier, as part of CCAR, monthly, quarterly and annual reports containing detailed data need to be submitted to regulators under FR Y-14 requirements. Additionally, this data need to be reconciled with FR Y-9 submissions. Since the data calculations and projections developed under both ICAAP (for overall capital adequacy purposes) and CCAR (for capital plan and capital actions decisions) are used for key strategic decisions, it is important to establish robust data controls.

In addition to process and data controls, independent model review and validation is another critical control aspect that needs to be emphasised in order to establish a robust capital management programme. The scope of independent model review and validation from CCAR perspective would apply to all the models used in developing base-case and stress projections. These would include models used for projecting assets and liabilities (including deposits), revenue, expenses and losses, as well as aggregation models. From an ICAAP perspective, all models used for capital adequacy purposes would be subject to review and validation. These would include Pillar 1 minimum risk-based capital calculations, and additional quantitative modelling performed under Pillar 2 (ie, models for capturing missing risks and models for developing different views of capital adequacy, in addition to Pillar 1-like economic capital and stress testing). Finally, for a strong internal control environment, a periodic independent review of the overall capital management programme is recommended by both ICAAP and CCAR. This expectation highlights the clearly established role of the internal audit function within the capital management programme.

As evident from the above analysis, both ICAAP and CCAR are initiatives geared towards establishing a comprehensive capital management programme at banks. Each of them has its own specific requirements and, at the same time, has significant overlap with the other across various functions. Banks would benefit from integrating governance- and processes-related requirements that are common between ICAAP and CCAR, and from implementing a comprehensive capital management programme.

CAPITAL MANAGEMENT APPLICATIONS

Methodologies utilised by financial institutions to measure and assess their capital positions have become substantially more sophisticated over time. In the wake of the financial crisis, regulators, board members and shareholders have all increased their focus on initiatives designed to strengthen capital management practices. Expectations with regard to how banks manage and assess capital adequacy have moved away from utilising methods that only focus on regulatory capital ratios to implementing capabilities that allow financial institutions to develop an understanding of their capital positions in the context of all risks faced by them, and the possibility of deterioration of their capital positions during internal or external stress events.

Regardless of which capital applications are used or which methodologies are employed, the objective remains the same: accurate management and understanding of a company's capital position. This understanding helps to facilitate a bank's ability to maintain capital levels that allow it to manage business activities through both normal and adverse business environments, maintain access to sufficient funding sources and realise opportunities for strategic growth.

At most sophisticated financial institutions, the capital management process focuses on three primary areas. The first involves identifying desired levels of capital that will protect shareholders and allow the company to safely operate in both stable and stressed conditions. The second involves assessing current and projected levels of capital against the limits that have been established to determine whether the current level of capital is sufficient. The third involves utilising this assessment of capital to evaluate businesses on a risk-adjusted basis, and to determine what (if any) capital actions can and should be executed by the company, including using capital to fund future initiatives, to achieve optimum capital allocation. The combination of these three activities represents the foundation of sound and effective capital management. As described in the previous sections, capital management practices have evolved significantly from a simple risk-based minimum capital view to more sophisticated and comprehensive capital adequacy assessment programmes, including Basel II and ICAAP, Basel III and CCAR. These advancements have taken place not only in the methodologies and calculations, but also around comprehensive coverage of all risks and, most importantly, establishing different approaches to evaluating current and projected capital that include Basel III's minimum capital requirements, banks' internal assessment based on economic capital and CCAR-based assessment under different stress scenarios. The banks need to implement a comprehensive capital management framework that incorporates all these advancements. Such a capital management framework should be used to support these key capital management applications, as will be described in detail below.

Capital targets and limits setting

Bank capital is one of the main expressions of a bank's risk appetite. In establishing its capital limits framework, a bank should implement various tiers of accepted capital position in terms of limits, guidelines and targets. Various views of capital should also be evaluated and incorporated in defining the bank's capital limits. These views may be based on regulatory requirements, the bank's own internal views based on economic capital or other similar methodologies and scenario-based capital limits. A bank's capital limit-setting process may include different layers of limits and targets, including absolute minimum regulatory capital-based limits, bank's internal limits above regulatory minimums, capital guidelines that may be used as triggers prior to reaching internal limits and capital targets that are the levels the bank wants to operate at under normal business conditions. Such an approach would encompass the different capital programmes described earlier. It would utilise the regulatory capital-based minimum requirements, apply additional capital based on ICAAP to capture additional risks, use internal bank assessments based on economic capital or similar methods and finally apply stress scenarios as required by both ICAAP and CCAR.

Minimum regulatory capital requirements

The first step to managing an institution's capital position is to understand the levels of capital that are required to effectively operate the business under both normal and stressed operating conditions. These capital levels are unique to each specific institution and represent a product of both the financial position and risk appetite of the company. Capital limits are implemented to help ensure that capital levels at the company are sufficient to generate market confidence and to provide access to capital markets in order to secure funding. While the standards have increased over time, regulators have been explicit when defining risk-based capital requirements for financial institutions. These risk-based capital requirements generally serve as the foundation used by banks to establish minimum limits on their capital levels.

Basel III regulatory capital represents the next set of international standards for levels of capital that financial institutions must maintain. Although not yet fully implemented, the guidelines from Basel III are being used at a majority of the largest financial institutions to help define the absolute minimum levels of capital that they must maintain.

While the "well-capitalised" guidelines establish the absolute minimum levels that banks must maintain to convey adequate capital positions and avoid regulatory imposed restrictions or actions, it is generally accepted that banks should be operating at some internally defined level above these standards. As explicitly referenced in the Federal Reserve's SR 99–18 (SUP):

> "[R]egardless of the techniques used, nearly all US banking organizations have found it advantageous to operate within capital levels above regulatory minimums, and indeed, above levels defined as 'well-capitalized' by regulation. Such decisions recognize supervisory expectations for strong capital positions, the cyclical nature of credit risks, the uncertainties and errors associated with measuring risk, pressures from significant business counterparties and other market participants, geographic or industry concentrations, business uncertainties associated with specific banking activities, and other factors not considered in the current risk-based capital framework."[8]

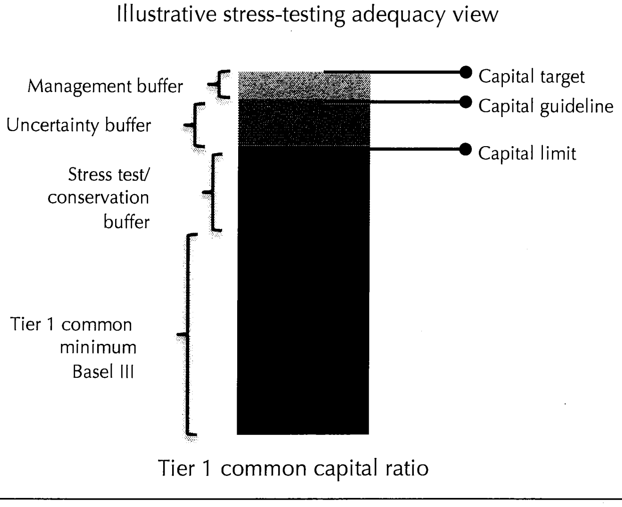
Additional regulatory guidance indicates that supervisors generally expect banks to hold capital proportionate to their unique risk profiles and to account for all material risks. This generally means that regulatory minimums should only be used as a floor when measuring risk-based capital, and that banks should layer on additional capital requirements to capture these other considerations.

These increases on top of regulatory required minimum levels of capital should ensure that the capital management process includes capital limits that take into consideration all material risks, quantifying those that can be reliably measured and establishing buffers for those risks that cannot be accurately quantified. This is one of the main concepts of ICAAP as described earlier. Additional capital add-ons should enable banks to maintain a capital position that covers capital dilution that will occur during periods of stress, uncertainty for risks not captured in the capital adequacy process, uncertainty for quantified risks and uncertainty due to material weaknesses in the capital adequacy assessment process. Furthermore, banks should manage their capital levels to include additional capital buffers as estimates for future business initiatives and strategic objectives. This approach to layering additional capital on top of existing regulatory required minimums is captured in Figure 14.3.

Stress-test/conservation buffer

While Basel III generally prescribes a 2.5% conservation buffer, the exact level of this buffer should be specific to each institution and

Figure 14.3 Capital limit, guideline and target methodology illustration for the Tier 1 common capital ratio


Illustrative stress-testing adequacy view
Management buffer
Uncertainty buffer
Stress test/ conservation buffer
Tier 1 common minimum Basel III
Capital target
Capital guideline
Capital limit
Tier 1 common capital ratio

based upon internal analysis that estimates possible losses that would occur during different stress scenarios or that have been historically experienced during economic downturns. Stress tests such as CCAR provide one relatively straightforward framework for banks to estimate and understand the potential magnitude of this need. Stress tests using CCAR also provide an estimate of capital requirements under stress scenarios and form an input for establishing a bank-specific conservation buffer. The stress-test buffer allows banks to manage their capital during times of normal operating conditions at a level that is conservative enough to safeguard the institution against possible losses that could occur as economic conditions deteriorate.

Uncertainty buffer

Sound capital management is based on a bank's ability to effectively measure and quantify all material risks faced by the institution and to maintain a capital position that is sufficient to protect the bank against those risks. However, accurately measuring and quantifying the impact for all potential risks that could diminish a bank's capital is a highly imprecise process. Consequently, banks should establish additional capital buffers to capture the uncertainties inherent in that process. These uncertainties are generally categorised into the following three areas:

- uncertainty due to risks not captured in the capital adequacy process ("missing risks");
- uncertainty due to quantified risks; and
- uncertainty due to material weaknesses in the capital adequacy process.

Banks that are most successful in leveraging these additional buffers work to ensure that they are applied in a transparent and consistent fashion. That is, rather than incorporating uncertainty buffers directly into the models themselves, separate line items are shown for each buffer. In addition to increasing transparency, this helps to ensure that buffers are not redundant and that risks are not double-counted.

Management buffer

Additionally, banks should manage their capital levels to include additional capital buffers as estimates for future business initiatives and strategic objectives. Actions that will result in future capital disbursements should be considered in capital planning, and capital levels should be maintained in such a way as to assure capital adequacy after the actions have been taken. Whether it is dividend distributions to shareholders, share buy-backs or equity capital used for merger and acquisition activities, the impact of these actions should be accounted for as part of a management buffer, and capital should be managed with these strategic objectives in mind.

Economic capital-based limits

In addition to the regulatory capital-based limits, banks also incorporate economic capital-based limits as part of their capital limits framework. Economic capital limits provide an additional view of the minimum capital a bank should hold to meet unexpected losses. When establishing economic capital-based limits, banks may incorporate some of the same considerations and methodologies that they use in establishing regulatory capital-based limits, guidelines and targets. These include reliance on a material risk identification and assessment process, incorporation of various uncertainty buffers and a management buffer. Economic capital-based calculations and limits can be thought of as a challenger view to regulatory capital calculations, in that they may reflect different parameters and correlation estimates not contemplated under Pillar 1 regulatory capital calculations. Additionally, many banks use economic capital under their ICAAP programme as a means to capture risks that are generally not captured under Pillar 1 calculations. In either case, economic capital provides an additional capital view to establish capital limits and guidelines.

Capital adequacy assessment

Once a bank has established the desired levels of capital that should be maintained at the institution through the selection and setting of capital limits, it must periodically evaluate the adequacy of its current and projected capital levels. This evaluation helps to ensure that the bank's current and projected capital positions exceed these limits and provides confidence that the bank is adequately capitalised. In a business-as-usual environment, banks will generally assess capital adequacy on a quarterly basis; however, during times of stress or increased volatility, banks may increase the frequency of this assessment.

To fully understand the capital position and demonstrate adequacy, it is necessary to view the capital adequacy assessment through a variety of different lenses. Each of these views either offers support for the bank's case that sufficient capital exists at the institution or evidence that capital levels are insufficient in the context of that particular test. While capital adequacy can be tested based on a wide variety of considerations, the primary ways that banks view adequacy assessments are described below.

Regulatory capital ratios – normal operating environment

Capital adequacy assessments for regulatory capital ratios involve comparing calculations for current and projected regulatory capital ratios to the capital limits, guidelines and targets. Under normal operating conditions, the ratios utilised in this analysis are generally capital ratio projections based on a baseline forecast or those derived through the standard business planning processes. This allows a bank to assess its most recent actual ratios (in addition to the projected capital ratios) in relation to the capital thresholds derived from the combination of regulatory expectations, the bank's risk appetite and the estimated impact that various factors could have on the bank's capital position. Regulatory capital ratios utilised in this adequacy assessment process include the Tier 1 common ratio, Tier 1 capital ratio, total risk-based capital ratio and the leverage ratio.

Use of this spectrum of regulatory ratios ensures that a bank is assessing adequacy across all forms of loss-absorbing capital components (eg, common equity, preferred stock, subordinated debt). Additionally, assessing adequacy for each regulatory ratio helps exhibit compliance with regulatory expectations and management of regulatory risks. While the Tier 1 common capital ratio has gained momentum as the primary ratio to be considered, it is important to assess capital positions separately across each of these regulatory ratios.

Levels of current and projected capital ratios are directly compared to the limits or guidelines established by a bank in order to gauge its capital composition. When capital levels are projected to be above a bank's targets over a projected period, a bank can conclude that it has adequate capital based on regulatory capital ratios under normal circumstances. Demonstration of capital adequacy under this test indicates that a bank's projected capital position under normal operating conditions can sufficiently meet regulatory expectations and withstand capital dilution caused by possible stress events, uncertainty and proposed strategic actions that affect capital.

Regulatory capital ratios – stressed business conditions

While understanding whether a bank is adequately capitalised under a baseline environment is critical, ICAAP and CCAR also require assessing capital under different stress conditions. Although ICAAP first recommended the idea of capital adequacy under stress scenarios to supplement the routine capital adequacy assessment, CCAR took it to the next level by accelerating the implementation of this requirement through the capital plan rule and the DFAST rules. CCAR requires banks to be able to perform integrated stress-testing activities based on fixed, stressed economic scenarios in order to generate *pro forma* balance sheets and income statements. Stress tests are aimed at determining the impact of adverse economic environments on banks' capital positions.

The capital adequacy assessment for this method compares the projected, stressed and quarterly values for each capital ratio against a bank's limits. Because capital ratios reflect a capital position that has already accounted for capital dilution that would occur during stress, the limits and guidelines used for comparison should no longer include capital allocation for the stress-test conservation buffer. Additionally, during times of stress, management would generally postpone any strategic actions such as future acquisitions or additional capital distributions, so capital reserved for the management buffer would not be included in the comparison of projected values to capital limits and guidelines. Banks are able to conclude that their capital positions are adequate when the projected values for the ratios, after recognising capital dilution created by the stress situations, still exceed the bank's limits.

Economic capital adequacy

As previously discussed, banks utilise economic capital to estimate unexpected losses that might threaten their solvency. Banks will determine the estimated economic capital values for a series of risk types, including market risk, credit risk, operational risk and strategic/business risk. These estimated values are aggregated (and generally decreased by a correlation adjustment) to produce a finalised estimate for economic capital at a bank. To allow for additional conservatism, economic capital values are then increased in line with the estimates determined for uncertainty buffers.

Because estimates of economic capital include different assumptions than regulatory capital ratios, assessing adequacy against economic capital calculations provides a bank with another adequacy test. When assessing adequacy, banks will compare the total estimates for economic capital to the capital available at the bank (generally represented by common equity) to determine whether the bank is currently maintaining a sufficient capital position.

Peer analysis

When providing support for capital adequacy, banks will often perform peer benchmarking to determine how their capital position compares to the capital position of selected peers. Most often, peer benchmarking takes the form of comparing historical capital ratios among a selected peer group to assess the relative capital position of a bank. However, with the movement toward standard regulatory expectations for completing CCAR and DFAST exercises, banks have become able to benchmark projected capital-related information that is made public.

Historical peer analysis is a common practice at banks. This type of peer analysis is used as a mechanism for analysing a bank's capital levels in relation to perceived market expectations based on capital positions of the bank's competitors. While this analysis is not 100% accurate due to differences in the size, complexity and risk appetite of each individual bank, the analysis does provide useful information on the adequacy of capital positions at a bank as compared to other financial institutions. Generally, banks will review at least eight quarters of historical capital information for each regulatory capital ratio to identify comparative capital levels and trends. Although not a sufficient method for assessing adequacy if used in isolation, this can be a useful method for supporting capital adequacy assessments when combined with other assessments.

Additional adequacy considerations

In addition to the primary methods used by banks to assess capital adequacy, financial institutions will perform a number of supplementary reviews to ensure that a bank's capital position is sufficient. The assessments will differ based on the unique needs of each institution, but can include aspects such as capital adequacy for each legal entity or capital adequacy in light of updates or changes to regulatory regimes. Regardless of the mechanisms used to determine capital adequacy, it is important to remember that no single method is sufficient to determine whether a bank can claim, without reservations, that its capital position is adequate. Banks must implement a variety of methods to assess capital adequacy and use results from each of these assessments in combination with one another in order to be able to truly evaluate their capital position and demonstrate capital adequacy.

Performance evaluation, capital optimisation and capital decisions

Beyond assessing capital adequacy, the most strategic application of the capital management framework is to establish a basis for senior management to evaluate the risk-based performance of a bank and make capital action decisions most likely to optimise capital allocation. This has become especially crucial since the financial crisis, which very clearly underlined the fact that capital is not abundant, but rather is the most critical scarce resource that could demonstrate a bank's financial strength and viability to the market. We will now provide details on how banks should utilise their capital management programmes to support risk-based performance evaluation and capital towards optimising their capital allocation.

Risk-based performance evaluation

Performance evaluation is a comprehensive exercise that should rely on multiple financial and risk data inputs, and take an integrated view. This includes financial data, including balance sheet and profit and loss (P&L) at the overall bank level, as well as performance by LOBs and portfolios at various granular levels. Risk data, including risk exposures and quantification, as well as risk-based capital allocations, need to be overlaid on top of financial data to develop a view of risk-adjusted performance assessment. As described earlier, capital adequacy assessment should apply different methods of assessment of required and available capital components, including risk-based minimum capital, economic capital and forward-looking projections under base case and different stress scenarios.

Such an analysis generated for a comprehensive capital adequacy assessment should include *ex post* as well as *ex ante* views in terms of historical performance and forward-looking projections as described in Figure 14.4.

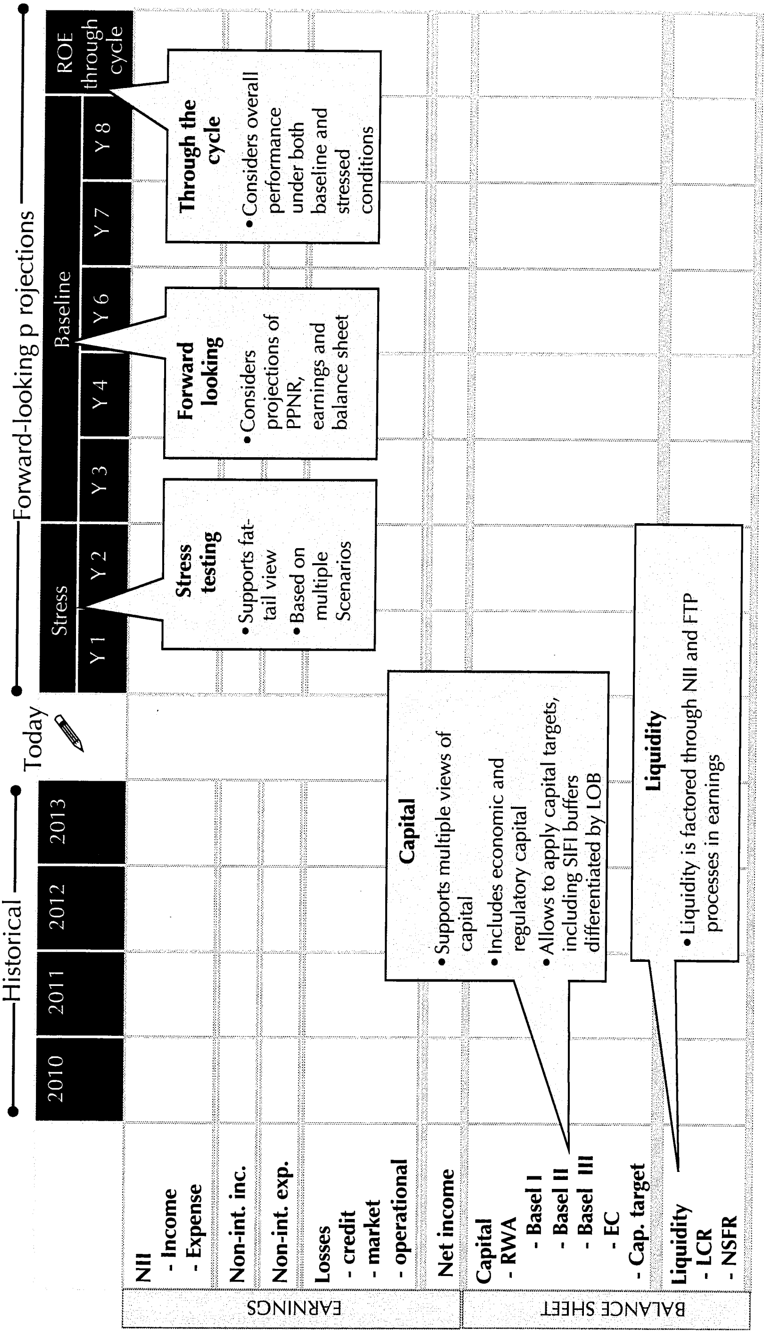
The historical overall performance of a bank, as well as its performance by LOBs or portfolios, can be evaluated on a risk-adjusted basis through economic capital allocation under the bank's internal view, as well as through RWA allocation under a regulatory capital view. Additionally, CCAR and DFAST projections provide a forward-looking view under different scenarios by applying business- or portfolio-specific assumptions for projecting the key components of assets, liabilities and P/L for each balance-sheet line item, as well as for the overall bank. An ideal capital management programme that allows a bank to thoroughly assess risk-adjusted performance would have the following characteristics:

- ☐ use of risk, capital and funding measures across segments, geographies and legal entities; different views of risk-based capital calculation and assessment, including regulatory capital and economic capital;
- ☐ further integration of finance and risk to provide risk-adjusted performance evaluation;
- ☐ flexibility to forecast the impact of evolving regulatory rules (Basel III, liquidity coverage ratio (LCR)/net stable funding ratio (NSFR), etc);
- ☐ adoption of regulatory scenarios and alignment with stress-testing guidelines (CCAR and DFAST); and
- ☐ technological improvements to enhance data quality and to automate reporting, linking incentives to risk appetite, profile and business activities.

Capital optimisation

One of the main decisions that banks need to continually assess is the level of capital they need to hold at any point in time and under different conditions. On one hand, banks want to use any excess

Figure 14.4 Historical and forward-looking performance assessment



Stress testing

- Supports fat-tail view
- Based on multiple Scenarios

Forward looking

- Considers projections of PPNR, earnings and balance sheet

Through the cycle

- Considers overall performance under both baseline and stressed conditions

Capital

- Supports multiple views of capital
- Includes economic and regulatory capital
- Allows to apply capital targets, including SIFI buffers differentiated by LOB

Liquidity

- Liquidity is factored through NII and FTP processes in earnings capital they may have toward revenue- and profit-generating activities; on the other hand, banks need to hold sufficient capital to protect themselves from any potential risks. Risk-adjusted capital calculation has been one of the main tools for banks to maintain this balance and make capital decisions. With the advent of enhanced methodologies, standards and approaches on one hand, and the improved data quality, granularity and system capabilities on the other, banks' ability to perform risk-adjusted capital calculations has significantly increased, allowing them to continue to optimise their capital positions.

The banks will have to continue to apply various strategic and tactical levers in order to continuously optimise capital and increase profitability at the same time. Some of these strategic levers for capital optimisation include:

- reallocating capital among LOBs and products, incorporating *pro forma* return on capital analysis;
- incorporating capital information into product pricing;
- optimising booking model and legal entity choices to capital-intensive transactions; and
- providing capital-based decision-making tools to business units.

Some of the tactical levers for capital optimisation include:

- refining exposure and RWA data quality and granularity;
- improving operational processes/policies that affect how capital is calculated; and
- refining RWA models and methodologies.

Capital decisions and capital contingency actions

Finally, the capital management programme should also include capital contingency plans along with a decision-making framework regarding preserving, generating and distributing capital under BAU and stress conditions. A bank's capital adequacy assessment process can have one of two results: a determination that the bank's capital position is sufficient, in which case the bank may elect to implement planned capital actions, or that the bank's capital position is insufficient, in which case the bank may need to execute capital actions with the intention of improving capital levels at the bank.

As previously discussed, assessments of capital adequacy occur generally on at least a quarterly basis. These assessments are performed after considering the planned capital actions that will be implemented by an institution. Banks must demonstrate that they are able to maintain adequate capital levels after taking into consideration any proposed capital actions. These assessments allow banks to understand whether they can meet the proposed actions and whether any additional excess capital exists that could be distributed back to shareholders. Assessments of adequacy help banks adjust current or proposed capital actions and shape future capital actions.

To be able to follow through with capital actions, capital adequacy assessments must demonstrate that excess capital is available and that, after distribution of the selected amount of this capital, a bank would still remain adequately capitalised. Upon the determination that excess capital is available, banks can elect to implement a variety of actions, including:

☐ maintaining the status quo;
☐ distributing new dividend or increasing current dividend;
☐ distributing special cash dividend;
☐ repurchasing shares; and
☐ making strategic acquisitions.

In the event a bank determines that its capital position is insufficient, it may become necessary to implement additional capital actions aimed at improving the level or composition of capital. During these situations, a bank is generally required to develop an updated capital plan that captures the impact these capital actions would have on improving its capital position, thereby allowing the bank to demonstrate capital adequacy. The newly implemented actions must be sufficient to offset any events that initially pushed the institution into an inadequate state. These actions will generally fall into one of two categories: either they are aimed at conserving capital that will increase capital levels, or they are focused on capital growth through securing additional capital and increasing the capital base.

Any capital actions taken will depend on the circumstances that exist at the time when capital was determined to be insufficient. The actions are assessed based on their cost and impact on improving the bank's capital position. While a wide variety of options exist, some of the most common types of action that are considered by banks to improve their capital positions include:

- ☐ postponing or cancelling acquisitions;
- ☐ adjusting dividends;
- ☐ adjusting planned stock repurchases;
- ☐ selling assets;
- ☐ issuing common equity;
- ☐ issuing non-common equity;
- ☐ converting capital; and
- ☐ reducing off-balance-sheet assets.

CONCLUSION

Capital management has been an ever-evolving area for banks, and CCAR is the next step in this evolution, as this chapter has described.

As banks continue to implement CCAR programmes, they need to treat this as an opportunity to enhance their overall capital management frameworks by leveraging and integrating existing regulatory capital, economic capital and stress-testing initiatives, rather than treating CCAR as an additional regulatory requirement that needs to be dealt with in isolation. This is especially the case since the objectives and the requirements of CCAR complement other existing initiatives and build upon those instead of replacing them. The most suitable approach for banks to take their capital management practices to the next level would be to start with the definition of a target state capital management framework that comprehensively integrates all regulatory requirements (Basel III, including ICAAP, and CCAR), as well as banks' internal best practices around economic capital and stress testing. Once a comprehensive target state capital management framework is defined, banks can identify specific areas of integration and enhancements within their existing practices and initiatives to achieve the target state. The key components of such a comprehensive programme should include sound governance practices, end-to-end capital management processes and appropriate internal controls and supporting infrastructure.

Capital management governance

Key components of a sound capital management governance include adequate oversight by the board, complete commitment from senior management in implementing the programme, appropriate reporting at different levels, appropriate committee structure at management and board levels to escalate and resolve issues, and comprehensive documentation, including capital policy and procedures.

End-to-end capital management processes

As various capital management initiatives are integrated, the focus should move from narrowly defined processes that support specific initiatives and requirements, to broader, end-to-end processes that are aligned with each other. Such processes should cover the entire risk and capital management processes from the planning, execution and evaluation stages of the business cycle. Processes included in a leading capital management programme would include: strategic planning and risk appetite processes; material risk identification, assessment and measurement processes; planning, budgeting and forecasting processes; detailed scenario generation and financial forecasting processes, including projecting assets and liabilities (including deposits), revenue, expenses and losses; capital adequacy assessment, capital planning, allocation- and distribution-related processes; and capital and liquidity contingency processes. The capital adequacy process should apply different views of capital adequacy that encompass regulatory capital, economic capital and stress-testing analytics.

CCAR internal controls

Establishing adequate and sound internal controls for the overall capital management programme is one of the most critical components, as it drives the integrity of the capital plan and related decisions. Main aspects of sound internal control practices include: periodic independent review by internal audit; data quality and data integrity; independent model review and validation; and comprehensive documentation of processes, procedures, results, weaknesses and planned enhancements. Controls around data quality and data integrity are extremely important due to new requirements around periodic submission of granular data to the regulators, reconciliation with FR Y-9c and public disclosures. The programme also needs to ensure compliance with SR 11–7 model risk management guidance, as it uses extensive modelling and calculations for balance-sheet and P/L projections, as well as aggregation.

1 76 *Federal Register* 74631–48.

2 CCAR applies to all US BHCs with US$50 billion or more in total consolidated assets and non-bank financial companies designated by the Financial Stability Oversight Counsel (FSOC) as systemically important. DFAST applies to all US BHCs with US$10 billion or more in total consolidated assets and non-bank financial companies designated by the FSOC as systemically important.

3 The semi-annual or mid-cycle company-run DFAST applies only to US BHCs with US$50 billion or more in total consolidated assets and non-bank financial companies designated by FSOC as systemically important.

4 Federal Reserve Board, 2013, "Capital Planning at Large Bank Holding Companies: Supervisory Expectations and Range of Current Practice", August.

5 The Federal Reserve Board delayed DFAST rule for domestic BHCs with US$50 billion or more in total assets that had not participated in CCAR 2012 or SCAP until the stress-testing cycle beginning October 1, 2013. 12 CFR part 252, subpart G. CCAR 2013 involved 18 BHCs.

6 Foreign firms with US$50 billion or more in total assets and combined US$10 billion or more in US assets are required to form an IHC.

7 While both CCAR and DFAST involve stress testing, CCAR is much more comprehensive than DFAST. CCAR involves an assessment of BHCs' risk profile, capital adequacy, capital plan, capital planning process and stress-testing methodologies (among other things), while DFAST is limited to a stress-testing exercise.

8 Federal Reserve Board, 1999, "Supervisory Letter SR 99–18 (SUP) On Assessing Capital Adequacy", July 1.

15

EU-wide Stress Test Versus SCAP and CCAR: Region-wide and Global Perspectives

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The European Banking Authority (EBA) is required by its founding regulation to initiate and coordinate EU-wide stress tests to assess the resilience of banks to adverse market developments. The first such stress test was performed by the Committee of European Banking Supervisors (CEBS), the EBA's predecessor, in 2009. The individual results of the stress test were kept confidential. In 2010, CEBS performed another EU-wide stress test, and this time an aggregate report as well as individual bank results were published.

Building on the experience of two previous stress tests, the newly established EBA conducted a stress test among 91 banks in 2011. This exercise was undertaken in coordination with national supervisors, the European Systemic Risk Board (ESRB), the European Central Bank (ECB) and the European Commission (EC). The objective of the stress test was to assess the solidity of the EU banking system and the solvency of individual institutions to stress events. The 2011 EBA stress test was a constrained bottom-up exercise. Banks were required to use their internal models for estimating possible losses, although the EBA identified common minimum methodological assumptions and imposed a single adverse scenario (see Bisio, *et al*, 2013).

The design of the methodology was a challenging task aimed at striking a balance between realism, comparability and conservatism, respecting the banks' specificities while ensuring consistency of treatment and results. While this is not different from other system-wide exercises, including the US one, the EU setting required extra effort to ensure consistency across intermediaries belonging to different jurisdictions and subject to not fully harmonised rules and supervisory practices. A key assumption – which probably marks the main methodological difference with the US – was the static balance-sheet assumption, ie, considering banks' balance sheets as static over the time horizon of the exercise and not allowing any management actions for mitigating the impact of the adverse scenario.

While conceived as very similar exercises, at least in terms of their final goal, the EU-wide stress test and the US Supervisory Capital Assessment Program (SCAP) performed very differently, with the former heavily criticised for its inability to deliver credible results and thus restore confidence concerning the robustness of the EU banking sector.

Leveraging on previous ones, this chapter will compare the EU and the US experience and try to disentangle the reasons why the two stress tests have been perceived so differently by market participants. The chapter will also suggest possible options for system-wide stress tests looking ahead, and propose some considerations on the feasibility of a global stress test, at least for systemic institutions. The aim is not to provide final answers on the design of a future stress-test exercise in Europe and at the global level, but rather to trigger discussion and provide some food for thought.

SYSTEM-WIDE STRESS TESTS: EBA STRESS TEST VERSUS US STRESS TESTS

The stress-test exercises run by the US Federal Reserve and the EBA during the financial crisis are often directly compared, focusing on their ability to support banks and restore market confidence. The common view is that the US stress test was successful in restoring confidence while the EU-wide stress test did not fully achieve this goal.

In this section, we will broaden the assessment and compare and contrast the US and the EU exercise, looking at the comprehensiveness of methodology, consistency of definition of capital, diagnostic tools for assessing and benchmarking banks' results, and the level of disclosure of the outcome. Our hypothesis is that the EU-wide stress test might have been less effective as a crisis management tool, but it did provide useful analytical tools in a highly heterogeneous setting.

Governance matters

As a starting point, we need to clarify the governance of the EU-wide stress test. While, in the US, the Federal Reserve plays a pivotal role in the banking supervision of major institutions and, thus, in the SCAP and the Comprehensive Capital Analysis and Review (CCAR), the responsibility for banking supervision is at the national level in the EU.[1] Accordingly, the founding regulation states the EBA is in charge of "initiating and coordinating" the exercise, and this task is performed in cooperation with many stakeholders, including the EU national supervisory authorities, their ESRB and the ECB.

Given the governance structure as well as EBAs' limited resource endowment, the EBA stress test is naturally, and correctly, based on a bottom-up approach – with first responsibility being on national supervisors in assessing and checking the stress-test results. In addition, no EU-wide backstop was available at that stage for banks failing the test and requiring financial resources.

Scope

The broad scope of the EU exercise is a defining feature, and difference, from other supervisory stress-test exercises. The large number of banks and wide geographical coverage in terms of different jurisdictions and frameworks is a formative feature of all design aspects of the exercise. In some senses, the EBA approach has been similar to the US stress tests, which included 19 firms (bank holding companies (BHCs) whose year-end 2008 assets exceeded US$100 billion). In comparison, the EBA covered over 65% of the EU banking system's total assets, at the same time requesting national jurisdictions to cover at least 50% of total assets in the home market (EBA, 2011c). However, the difference is the number of banks included in the exercise, which amounted to 91, operating in 21 national jurisdictions, with differences in supervisory and legal systems, albeit within a single market framework. These features drove the choices on methodology below, with a focus on consistency over idiosyncratic components.

Severity of the scenario and scope of shocks

The US SCAP and the EU-wide stress tests used a similar approach in their definition of shocks, with a view to challenging banks with extreme but still plausible shocks. This is easier to say than do, particularly during financial turmoil, and in the midst Europe performed fairly badly in the aftermath of the stress test. However, looking at some figures, the CEBS/EBA macroeconomic scenarios were tougher than the US SCAP ones. In the 2011 EBA exercise, for instance, the cumulative adverse growth shock in 2011 averaged 1.5 standard deviations (CEBS, 2009: 1.9 standard deviations; CEBS, 2010: 1.3 standard deviations), while the US SCAP applied a cumulative growth shock of 1 standard deviation. Still, the forecasted macroeconomic variables matched the actual economic environment observed in the period 2011–12. In addition, for some countries the actual outcome was subsequently worse than the adverse scenario, implying that the adverse scenarios for southern European countries in particular were too mild. Indeed, the milder US scenarios, especially the SCAP 2009 scenario, was effective in restoring market confidence while the EU scenario was not as convincing, mostly because of the missing sovereign shock.

Apart from the severity, it was also stated that market movements – particularly for sovereign exposures – overtook the adverse scenario during the EU-wide exercise before the results were published. This is only partially true. In fact, the EBA constantly monitored credit default swap (CDS) spreads for corporate and financials, stock indexes and market volatility indicators during the exercise in order to take appropriate action when needed. While the EBA did not find evidence on most of the indicators, it did identify a worsening of sovereign spreads, especially for peripheral countries, and reacted by adding appropriate sovereign haircuts to the existing scenario and methodology. In addition, real-time updates of the scenarios are hardly manageable within the timeframe of a system-wide stress test.

Idiosyncratic tailoring versus consistency in developing the methodology

With respect to methodology and supervisory analysis, the EBA ran a constrained bottom-up exercise across a large number of banks in different jurisdictions that entailed full reliance on banks' internal models. This, in turn, required the development of a comprehensive and detailed methodology *ex ante* in order to prescribe the computation and estimation of the scenario impact. Besides, the complexity of banks' internal models and estimation processes imposed a high level of methodological comprehensiveness. The EBA published the methodology in advance of the exercise, aiming at methodological transparency. The methodology was complemented by an extensive Q&A process and by employing a wide-ranging set of statistical benchmarks.

Differently from the US SCAP, EBA focused on a horizontal (ie, cross sectional) analysis of results. The main reason was that any vertical assessment (ie, bank-by-bank assessment) remained the responsibility of the national supervisors, while the EBA was entitled to conduct a peer review analysis to assure quality across the sample. This cross-sectional benchmarking (horizontal) analysis was an innovation in Europe. Conducted over a large cross-border sample of banks, and covering information previously under national monopoly only (eg, PDs and LGDs per portfolio and region), the EBA established the first comprehensive database of this kind in Europe. As an outflow of the issues observed in this data, the EBA initiated the review of banks' risk-weighted assets (RWAs) calculation.

The most obvious shortcoming was that the data quality, and especially the starting points provided, were not subject to a common EU scrutiny. Also, no statistical analysis of the outliers, even if sophisticated, can replace direct interaction with banks. Conversely, in the US, direct interaction with US banks facilitated the process of data validation from a centralised perspective.

Outcome of the stress test and supervisory measures

The EU-wide stress test was a pass/fail exercise, and banks were assessed against a common definition of capital. Similar to the US, the EBA assessment criteria has been defined more narrowly than the legally defined minimum regulatory capital in place at that time. Strikingly, the EBA identified for the first time a definition of core Tier 1 capital (Tier 1 minus hybrids) as the reference variable to be used for the stress test. This was a significant achievement considering that the definition of regulatory capital varied across the EU. Indeed, although the EU had implemented the Capital Requirements Directive (CRD) II on a common basis, national supervisors had room for discretion when transferring the EU law into national law.

The core Tier 1 capital benchmark was set at 5% of RWAs. In contrast to the US SCAP, the EBA referred to only one threshold or hurdle rate. However, the main driver of recapitalisation needs in the US arose from banks not achieving the stricter core Tier 1 hurdle rate (4%) than the 6% capital requirement referring to the existing capital requirements.

Overall, the EBA stress test in 2011 revealed a capital shortfall of €26.8 billion. Similar to the US SCAP, banks took capital measures between January and April 2011 of approximately €50 billion that were incorporated in the results. By allowing some capital measures taken by banks to pre-empt the stress test, the actual shortfall was rendered to €2.5 billion. The shortfall was attributable to 20 banks, representing about 22% of the sample (EBA, 2011a).

Despite limited powers, the EBA did follow a course of corrective supervisory action that is best assessed from an intertemporal perspective. It stated in a press statement on March 18, 2011: "The stress test assesses what might happen to banks if external circumstances deteriorate markedly and helps to identify vulnerabilities and relevant remedial action, including strengthening capital levels where this is needed." Thus, the EBA acknowledged the role of its stress test as having become a crisis-resolution tool. This included EBAs' commitment to strengthening capital levels. The results of EBA's stress test were published on July 15, 2011, and banks not achieving the 5% core Tier 1 capital threshold were requested to present a plan on how they would restore the capital position to a level at least equal to the 5% benchmark within three months. The measures were to be fully implemented by end of 2011 (EBA, 2011a). Moreover, the EBA recommended to national authorities they should also take corrective action towards banks above the 5% threshold but with significant exposure to sovereigns under stress to allow corrective action. Although the responsibility for follow-up measures was firmly the responsibility of national supervisors, the EBA further strengthened its recommendation for action with a recapitalisation exercise in autumn 2011, which saw a further (and arguably more successful) strengthening of EU banks' capital levels to 9% core Tier 1 capital after accounting for a sovereign buffer, and which led to a further €204 billion additional capital strengthening.

Disclosure of results

In microprudential exercises, publication is uncommon. The fact the EBA did publish the 2011 stress-test results represents once again the convergence of macro- and microprudential stress-test approaches to a crisis stress test. In fact, the EU stress-test results were accompanied by a level of publication not experienced previously on such a large scale. Similarly to the US, the results were disclosed on a bank-by-bank basis. In contrast to the US, however, the granularity of provided information was larger. In a fragmented supervisory community as in the EU, disclosing figures on a comparative basis across the EU represents an additional innovation. The disclosed figures were employed by external parties in their own stress-test models rather than relying on banks' internal estimates of losses and increases in RWAs. Enabling external parties to employ banks' figures independently represented an advantageous complement to th EBAs' sensitivity analysis. One might argue that the EBAs' publication approach created more transparency than any disclosure of selective results and figures that had gone before it. This contributed to a comprehensive understanding of risks and vulnerabilities in the EU banking sector.

The output metric for a crisis stress test relies mainly on individual bank data, and one of the more successful components of the EBA exercise was the publication of 3,400 data points per bank. In comparison to the US SCAP, the EBA published the results in a more granular manner from a qualitative, as well as a quantitative, perspective. As for the quality of disclosure, the EBA results displayed the single components of the solvency ratio plus the composition of capital and RWAs, along with estimated losses and provisions per regulatory portfolio. Since major concerns arose on sovereign holdings and the potential losses attributed to them, the EBA disclosed the actual sovereign exposures per bank, region, accounting category and maturity. The display of sovereign assets per accounting category enabled external parties to evaluate the silent losses sitting on banks' balance sheets on a stand-alone basis, while the EBA stress test itself did not mark-to-market sovereign holding in banks' banking books. This somewhat addressed the market perception that a weakness of the EBA stress test in 2011 was the lack of a sovereign default within the EU.

From a macroprudential perspective, the disclosure of sovereign assets on such a large scale had several benefits. For instance, analysts were able to assess cross-holdings and geographical dispersion of sovereign assets across the EU. This was a novelty.

OPTIONS TO CONSIDER IN REGION-WIDE STRESS TESTS

In the previous section, we discussed the similarities and differences between the system-wide stress test in the US and the EU. We also tried to understand why the US exercise was perceived as a circuit breaker, while the EU stress test in 2011 failed to reassure market participants and restore confidence in the banking sector. In this section, we will move to a more forward-looking analysis, and discuss the alternatives that supervisors face in choosing possible alternatives for future stress tests.

From our analysis in the previous section, it should be clear that the ideal framework for stress testing depends very much on the market and macroeconomic conditions at the time the stress test is run. Indeed, they affect the objective of the exercise and, thus, the choice of the most suitable approach, methodology and supervisory response. In that respect, the main question is whether the purpose of the stress test is the identification of immediate capital needs – in aggregate for the entire banking sector, as well as for specific institutions – or the scrutiny of risks and vulnerabilities in the banking sector. The former is typically necessary in a crisis stress test, and requires immediate supervisory reaction; the latter is a more traditional diagnostic tool to be deployed in normal times, with longer-term remedial action measures. Therefore, there is no single correct answer for all countries at all times. What is sensible in the middle of financial turmoil may be inappropriate when markets are calmer, and vice versa.

For example, in the EU, banks are in better shape than they were in 2011. According to most data collected by the EBA, the largest banks had – on average – a core Tier 1 ratio above 11% in December 2012. While there is cross-sectional dispersion, EU banks are sufficiently capitalised and there should be no concern regarding the quality and quantity of capital they hold. On the other hand, there remains uncertainty about the quality of the assets in the EU banking sector, as well as mistrust on the reliability of the models used for the calculation of RWAs.[2]

This raises a question for supervisors as to whether Asset Quality

Reviews (AQRs) are an integral and indispensable component of any stress test. Experience suggests that AQRs are a prerequisite for a stress test in some limited circumstances. For instance, they are necessary when there are initial concerns or uncertainty regarding the robustness and conservatism of banks' credit-risk estimates and provisioning policy at a time when market conditions heavily affect borrowers' ability to honour their obligations. As an example, the combination AQR/stress test has been the *leitmotiv* in all the so-called "programme countries" in Europe, as well as in other distress countries where banks were particularly weak because of the bursting of a credit bubble, the exposure to distressed sovereigns or, more generally, a challenging macroeconomic environment. Linked to this is the choice of a potential hurdle rate.

Therefore, what should supervisors be considering in the design of future stress tests? A key caveat is that no decision has been taken so far on the design and scope of the 2014 EU-wide exercise. In which case, we can only describe the possible options and analyse the pros and cons of different approaches for supervisors as a general exercise.

Still a pass/fail exercise?

The first question for the decision-makers is whether the stress test should be a crisis exercise with a predetermined pass/fail threshold with the expectations of immediate capital redress, or, rather, a forward-looking supervisory exercise. A crisis mode by nature requires immediate redress and, for example, the EU banking sector is in better shape than in 2011 – and "crisis mode" may well not describe the protracted period of repair that has been undertaken in the EU. When the preconditions for going beyond the pass/fail logic are met there can be a move back to the original function of stress tests – ie, to serve as a diagnostic tool for supervisors. A supervisory stress test following a broad AQR adds value for supervisors in terms of understanding and addressing residual risks. Going beyond the pass/fail approach also has side benefits. In particular, it reduces the incentives for banks and occasionally supervisors to behave in a beauty contest-type manner – to show they are solid banks and effective supervisors, thus improving the conservatism of loss estimates as well as the level of cooperation.

Which approach?

However, there are many other choices to be made in the design of a system-wide exercise, including the approach (bottom-up versus top-down), the desired level of harmonisation of the methodology, the range of risks to be covered and the sample of institutions in the scope of the examination. Even if the several ingredients of a stress test can be combined in many different ways and, thus, there is a continuum of options for running any exercise, it is more helpful for analytical purposes to discuss two corner solutions. In addition, for the sake of clarity and given the focus of this book, we use the Dodd–Frank requirements to provide the reader with easy-to-understand benchmarks.

A possible option is to go for a bottom-up exercise *à la* Dodd–Frank's "company-run" stress test (see Chapters 1 and 2 of this book). In this setting, the authorities would provide the banks with a methodological frame, which would only set some basic principles. In particular, the methodology would be limited to the definition of the scenarios (eg, baseline, adverse, severely adverse), the choice of the time horizon of the simulation (eg, nine quarters) and some limited constraints on managerial actions for all banks (eg, assumption on dividend payouts, repurchases, issuances of capital). A very strong and pervasive *ex post* review of banks' results would be the indispensable complement to a light methodology. The supervisory review would aim to assess the severity of the assumptions, the conservatism of the estimates and, as a bottom line, the credibility of the outcome. This can be coupled with the assessment of capital plans under the CCAR. As for the disclosure of the outcome, results would be published by banks under their responsibility, leaving the final say on the credibility of the exercise to market participants.

Note this approach is completely different from the 2011 EU-wide stress test. In this, the EBA enforced a detailed methodology along with constraints – particularly the static balance-sheet assumption – and statistical benchmark for banks, but could not carry out a thorough *ex post* assessment of banks' results, which were beyond EBA's legal remit and a challenge for a large sample of banks. Also, while the results have been first published by banks and re-published by the EBA, the responsibility of the outcome has been exclusively ascribed to the EBA.

The other corner option is to replicate the approach of the Dodd–

Frank "supervisory" stress test. This would be a top-down exercise based on common scenarios for all banks (in the US, the same used by the banks for the company-run stress test). The supervisory model should be – at the very minimum – able to estimate the losses under the scenarios. This can be done at different levels of aggregation, and there is clearly a trade-off between the accuracy of the estimates and data requirements. One extreme is to estimate losses for the entire balance sheet, only distinguishing by risk type. The other extreme is to use counterparty-by-counterparty data as banks would do in the company-run stress tests. Since both options have their pros and cons, a possible compromise would be to rely on asset class and country of the counterparty breakdowns. This would ensure sufficient precision in the estimation, while keeping the efforts in terms of data collection and manipulation manageable.

In principle, the evolution of other profit and loss (P&L) items could be proxied by looking at the historical experience; however, the model would ideally also include modules for projecting revenues and expenses in order to achieve a more realistic and accurate assessment of capital levels in the different scenarios. This would affect further the data needs.

The top-down methodology would allow for estimating the impact of the scenarios on each bank in the sample, although this does not necessarily imply the disclosure of bank-by-bank results. Authorities could, for instance, choose to keep the bank-specific results confidential and only publish aggregate figures, something not advisable in crisis times but perfectly adequate for a stress test in normal times.

Moving from the corner solutions to a more hybrid approach, strengthening the approach followed by the EBA in 2011 and overcoming its shortcomings remains an option and would be in line with the EBA's mandate to "initiate and coordinate" the EU-wide stress test. Based on our discussion in the previous section, the success of this approach would, however, require significant improvements. First, the methodology should remain detailed and prescriptive, closing methodological gaps identified and leaving little room for interpretation and national discretions. In addition, statistical benchmarks and, possibly, floors for risk parameters should be identified at an early stage and shared with the banks.

There should also be a clear *ex ante* understanding about their use in the quality assurance process.

However, the lessons from 2011 are not encouraging: the governance of an EU-wide bottom-up exercise is multi-layered and complex, benchmarks are data-intensive and difficult to fit, the acceptance for floors is limited. More generally, while constraints are the only way for ensuring the level playing field and comparability of outcomes in this kind of stress test, a too-constrained exercise is prone to the criticism of transforming a bottom-up exercise into a top-down exercise, while still imposing the costs of bottom-up ones on banks.

System-wide stress tests looking ahead

Where the EBA might actually position its stress test would depend on various factors. Company-run stress tests alone are not the solution and need to be accompanied by either some quality-assurance process for ensuring the reliability of the results or, as in the US, the publication of the supervisory top-down stress test as benchmark for market participants. As we have mentioned, a rigorous supervisory review should include the assessment of banks' assumptions, methodologies and outcomes. In an unconstrained bottom-up exercise, this is feasible only if the ratio of banks in-sample to supervisory resources is reasonably low and the authority in charge of quality assurance has a strong legal basis for interacting with banks and challenging their results. The publication of the results of supervisory stress tests is probably preferable to the extent they are based on good quality and granular data. Indeed, market discipline should ensure that companies have an incentive to produce reliable and conservative estimates. However, it remains unclear to what extent the publication of bank-by-bank results are consistent with a non-pass/fail exercise, and whether in publishing those results market participants will rank banks based on their post-stress capital levels anyway, and require recapitalisations. In that respect, the publication of aggregate results along with the disclosure of bank-by-bank actual/historical data (for instance, on risk parameters and exposures) may represent a way for informing and reassuring market participants without attaching too much emphasis to the pass/fail outcome.

In our view, top-down "supervisory" stress tests might have some appeal since they are less resource-intensive, particularly once the methodologies are developed, guarantee by construction the comparability of results and do not require any quality assurance, once the integrity of the data is assessed. As discussed, top-down stress tests can be also used in a very granular fashion if banks are required to submit detailed information. In fact, they might be as precise as banks' own simulations, but with the advantage of being based on a single model. A top-down supervisory stress test would also leave the flexibility to decide at any point in time whether the publication of individual results is desirable or not. In addition, it could be a useful tool in the assessment and challenge of banks' capital plans.

TOWARDS A GLOBAL FRAMEWORK FOR STRESS TESTING?

In this chapter, we have so far explored how stress testing in the EU has, in the past, differed from that in the US. Successful or not in its outcomes, the EBA does have a unique experience of stress testing across European jurisdictions. This experience is informative for any consideration of more widespread, cross-jurisdictional stress testing.

Although there are no imminent plans (or any that we know of) to undertake some form of global stress testing, there is reason to assess the possibilities for global stress testing as a theoretical "straw man" exercise. This could inform thinking about the extent to which, in a globalised world, micro- and macroprudential authorities may be able to build cooperative steps on stress testing, which over time would better inform the analysis of the risks in internationally active banks, provide an understanding of vulnerabilities in global financial markets and help market participants to make sense of the volumes of information about stress testing they receive.

The motivation to find commonalities in supervisory stress-testing frameworks is based on the EU experience that there are potential benefits to assessing banks consistently across jurisdictions, even if at times this is at the expense of more granular idiosyncratic stress tests tailored specifically for institutions and jurisdictions.

Benefits arising from micro- and macroprudential outcomes

At its most obvious, joined-up stress tests for a number of large cross-border banks can provide supervisors with useful peer group comparator information on a microprudential basis. A joined-up stress test can also create a level playing field for globally active banks, with supervisory response functions linked to capital outcome/other supervisory measures. While supervisors have made significant headway in agreeing global capital and liquidity rules, these rules are being seen through the prism of national stress tests applied in different ways and with different benchmarks across countries. A joined-up approach to stress testing at a global level could also create insights into potential links, transmission channels and feedback loops between institutions, and allow supervisors to test specific sensitivities from a cross-border perspective. It could also facilitate investigations into the links between banks and other non-bank market participants[3] and the financial infrastructure, including the effect of national policies domestically and globally.

The disclosure of coordinated and comparable information about stress tests would also help to improve market discipline and may help market participants and the general public understand better how stress tests fit into the suite of other information available about banks.

Areas for global coordination

To better draw out the experiences explained in the first two sections of this chapter, we outline here the elements of potential commonality in stress-testing frameworks that could be considered at a global level.

The comparisons in previous sections make clear that the role of supervisory stress testing in a crisis is specifically about recapitalising banks, and the banking system, to a higher level and to restore confidence in the banking system. This compares with the role of stress testing in more normal times, when the overall level of capital in the system is not in question and supervisors use stress tests as an analytical tool in conjunction with other instruments, such as supervisory risk assessments and banks' capital plans to challenge, and possibly change, the assumptions and actions underpinning those forward-looking capital plans. More systematic coordination of both the objectives and outcomes is an area of potential coordination. In the same context, the scope and frequency of supervisory stress tests could usefully be aligned to provide some certainty in planning and expectations for banks and market analysts, as well as the general public, and such coordination would also be a helpful first step to any future global stress testing. That would entail potentially a general stress test "season" for banks and some views on the focus areas in terms of banks (for example, the categorisation made in Dodd–Frank between supervisory stress tests for the largest banks and the requirements for the next tier of banks).

A second broad area where potential coordination could be considered over time relates to the substance of stress testing. For example, some commonality in scenarios could be considered both in terms of relative severity (for example, the anticipated degree of freedom of the adverse scenario from the baseline expressed in standard deviations, or once in *n* years). Of course, commonality of scenarios would not lead to consistent stress tests. That would require some commonality in methodologies. For example, it is not possible to compare a stress test with rigid assumptions focused on consistency, such as static balance sheets, with more flexible idiosyncratic stress tests that allow for a range of management-mitigating actions to be incorporated. Such coordination on methodologies could be incremental and focus on some basic assumptions, such as management actions, without agreement on every detail that may in any case be dependent on specific supervisory rules or judgement.

A third area of potential coordination is the assessment criteria used to challenge and measure the outcomes of stress tests. For example, coordination on projected loss rates by portfolio and geography would provide a consistent challenge for internationally active banks. On the other hand, coordination on likely assumptions on future revenues such as fees or net interest income would provide a common conservatism. An even simpler step than these challenge tools would be commonality of hurdle rates, or capital ratios, to be assessed under stress conditions. This may be an area that happens naturally under the new Basel III regime, albeit with commonly understood differences related to potential macroprudential capital buffers.

A fourth and final area of potential coordination relates to the outcomes of stress tests. Searching for common ground in the reporting of stress-tests results may help the broader public understand better what stress tests do and do not do. In particular, it may instil a sense in the public imagination of stress tests as a regular exercise that is just one piece of information among others. Such a perception may also be helped by some commonality in the degree of transparency in the starting positions of banks. Finally, considerations of coordination in terms of outcomes leads full circle to consideration of the original objectives of stress tests and their relationship with the supervisory reaction function. In addition, there is the consideration regarding the expectations of the public as to what types of actions will follow for banks, with a focus on the different expectations between a point-in-time focus on raising capital levels immediately and those of forward-looking adaptions to assumptions and planned actions by banks, recognising that of course these types of actions are not mutually exclusive, but there may be a weight of expectation on one or the others.

Operationalising a global stress-testing framework

Considering the numerous ways in which cooperation and collaboration on stress testing can benefit supervisors across borders, there is an obvious spectrum on which coordination of global stress testing could be considered, albeit with considerable challenges as we move along the spectrum. At one extreme is the potential for a single, common stress test – for example, on a number of globally systemically important financial institutions (G-SIFIs) – and at the other is a series of uncoordinated national stress tests. The EU has experience of stepping into this spectrum. In addition, although operating across a single market, this experience has nonetheless thrown up many of the challenges towards greater cooperation that would be manifest at a global level. For example, in 2011 the absence of a single supervisor and a single backstop, differences in supervisory systems and in some supervisory definitions, along with the challenge of applying a common methodology across a range of banks, provided fertile ground for understanding the larger challenges of any type of coordination internationally.

A single stress test

Taking the more extreme end of the spectrum, a single global stress test on a range of banks undertaken in the public eye[4] would face considerable challenges.

Such a global test would no doubt be a useful analytical addition to the suite of stress tests, with consistent information provided across internationally active banks allowing better peer comparisons and facilitating an assessment of potential vulnerabilities to global financial markets posed by banks. This would be from both a micro-

and macroprudential perspective – for example, interlinkages between banks, and between banks and the global financial system – and possibly shedding light on international repercussions of changes in domestic policy. Moreover, international coordination of such a stress test may improve the credibility of all supervisory stress testing by driving, and being seen to drive, good practice. At the same time, the exercise may have positive externalities, such as providing an impetus for convergence in areas such as key supervisory definitions that can create confusion in comparative analytics (for example, comparing such simple measures as leverage ratios or non-performing loans).

The first challenge is managing the suite of stress tests. It is likely that a new global stress test would be an addition to the existing suite of stress tests and would probably capture the public imagination, while national stress tests, where fiscal responsibility lies, would nonetheless remain dominant for decision-making.

Second, differences in national/regional financial systems and different market conditions would make the formation of a common but relevant scenario very challenging, and the outcomes possibly misleading. More telling in this regard, perhaps, would be the challenge of finding common ground on a methodology in the face of different regulatory systems, different definitions of key variables and different supervisory assessment systems.[5]

Finally, and perhaps even more challenging, would be the complexities of governance and incentives. Again recalling the challenges of keeping any meaningful and well-resourced stress test private, it would be incredibly complex to find common ground on issues such as definitions, where one country's banks may well be disadvantaged by compromises in this regard. In addition, of course, for all the rigour of any chosen methodology, as stress testing relies on judgement and complex governance, the incentives to always err on the side of conservatism may well not be present.

A stepping stone approach

If the challenges of a single stress test appear insurmountable, there remains the question as to whether any steps can be taken in the short term. Clearly, this is a rhetorical question given the heightened level of cooperation among banking supervisors in their agreements on global rules for capital and liquidity, and indeed the existence of guidelines on stress testing for banks. Nonetheless, drawing on the experience of coordinating a stress test across a single market does permit some insight into areas of potential further coordination.

There are some obvious avenues for cooperation that we will not labour here, including sharing of resources via short-term secondments and ongoing mutual exchange of good practices and lessons learnt. Such exchanges may be strengthened through a sharing of technologies regarding stress testing, including supervisors own loan loss forecasts. At the margin, this could work well for banks active in each other jurisdictions but over time may provide a more informed range of tools to provide challenge functions to banks' stress testing. The coordination may also benefit from more formal collaboration to produce a document of good practice, or even guidelines for supervisory stress testing. Such an exchange may well face some of the challenges outlined above regarding different definitions and supervisory systems, but a set of guidelines may well help inspire improving practices and importantly assist in determining the appropriate resource allocation to stress-testing activities in terms of people, skills, IT and data resources. A discussion around guidelines for supervisory stress testing may well inspire impetus to identify other stepping stones towards cooperation, including definitions, transparency and communication on stress testing.

The scope for common ground in scenarios and methodologies may well be limited by the need for scenarios and methodologies that appropriately reflect the relevant jurisdictional setting. Nonetheless, over time it is likely that common ground on scenarios (deviations from the baseline, types of shocks to be covered) could be coordinated to provide a single framework for the various stress tests carried out globally. Similarly, although a single methodology appears to be distant while different supervisory systems exist, there may be some areas where common ground could be found, whether that be the treatment of defaulted assets for credit risk, or approaches to market risk or securitisation where supervisors globally have tended to favour more simple approaches when undertaking whole firm stress tests so that they can concentrate on vulnerabilities to credit losses.[6]

The global work of the Basel Committee on capital and liquidity standards has achieved significant convergence regarding important definitions on capita, etc, although significant differences also remain. Obvious examples of these include definitions around asset quality, such as non-performing loans and forbearance. Many definitional differences reflect different legal and institutional settings, such as accounting and legal frameworks, and agreement on convergence may be impossible for supervisors acting alone and may even be dangerous if it then misrepresents the underlying risk as evidenced in the relevant country setting. Nonetheless, agreement on common definitions (core Tier 1, sovereign exposures, non-performing loans) is paying dividends in the EU by helping supervisors and market participants understand better the risks in context. This suggests that there is ground for improvement at a global level, and supervisors could usefully set a sense of direction towards finding common ground.

Such agreement on definitions and the presentation of risk information can be of great use for supervisory assessments, but also for improving market discipline through enhanced transparency. Indeed, as noted above, one of the successes of the EU exercise were the unprecedented 3,400 data points that were released per bank, and which helped market participants use more effectively the information from the stress tests.

CONCLUSIONS

In any supervisory stress test there are a range of considerations based on objectives, resources, number of banks and jurisdictions, etc. In this chapter, we attempted to focus attention on lessons learnt from the EU-wide stress test of 2011 against those from the US 2009 SCAP. These lessons shed light on the options for supervisors in designing future stress tests.

One can see from the above the differences in stress testing between the EU and US experiences, and which demonstrate the peculiarities of stress tests involving different jurisdictions, with different supervisors and different fiscal backstops. It is clear that within a common national framework, a single supervisory decision-making body, a common backstop, a single communication channel and focused and resource-rich cross-institutional teams, specific outcomes can be achieved, particularly associated with successful crisis stress testing and the transition to stress testing in more normal times. In this context, there are lessons to be learnt from the US experience of shifting away from crisis stress testing towards the focus of CCARs, which appears to address this point with a supervisory response function that is not immediate, or point in time, but a forward-looking approach to assessing capital plans and building a relationship between supervisory stress testing and company stress testing.

Conversely, the EU-wide stress-test experience offers lessons on supervisory stress testing across a large number of banks and jurisdictions without a single supervisor, without fully consistent accounting rules and no burden of sharing agreement/common backstops. In this context, it facilitates reflections on the possibilities around the convergence of methodologies but also on the need to sacrifice some aspects of idiosyncratic accuracy for consistency in the application of the stress, along with consistent definitions (eg, on specific capital measures or going forward on aspects of loan quality) and the value added of cross-fertilisation among mixed supervisory teams.

A constrained bottom-up methodology allows comparisons across large numbers of banks, while a purely bottom-up methodology run by banks also demands effective *ex ante* quality assurance metrics. At the same time, if the public is to understand better what stress tests do and do not do, and how the suite of stress tests come together, then there are benefits of enhanced transparency of methodologies and starting-point data. Such lessons are then useful for any theoretical considerations about further integration of stress-testing frameworks across borders (clearly flagged as a theoretical straw-man exercise in this chapter, and not a near-term possibility). The costs of such an exercise clearly point out the challenges in any move towards a meaningful global stress test but also, in assessing those challenges, shed light on those areas where supervisory cooperation may both be possible and valuable. There is clear benefit in identifying and maximising use of the common ground already in existence, and creating an impetus to further that ground to cover more of the landscape as possibilities arise.

The opinions expressed in this chapter are those of the authors and do not involve the EBA or its members.

1 In 2014, this setting will change somewhat as supervisory responsibility for a number of banks is passed to the single supervisory mechanism (SSM).

2 For this reason, the EBA has launched a comprehensive analysis of the consistency of RWAs across banks and agreed on a recommendation requiring national supervisors to carry out AQRs on the major banks. The main focus is clearly on the asset side and the identification of residual risks. The AQRs aim at addressing remaining concerns on "actual" credit quality. In other words, AQRs are the tool for disentangling the level of credit risk in banks' balance sheets, the extent of forbearance and any possible further capital needs ahead of the stress test. They also ensure that provisions and risk parameters – the starting point of the stress test – are adequately quantified.

3 The focus of this section is on the cross-border stress testing of banks. We do not enter into a discussion of cross-sectoral stress testing, domestic or international. However, based on early stage discussions between insurance, markets and banks supervisors, there are clear challenges in cross-sectoral stress tests. The temporal challenges for banks and insurers are different, if not contradictory, and thus scenarios and methodologies may be mutually exclusive, bar a global meltdown of apocalyptic proportions. Similarly, market- and infrastructure-type shocks may at best be coincidentally aligned with stresses for institutions, although an operational war game of a day of catastrophe may be of interest.

4 A private stress test, undertaken outside of the public eye, is theoretically possible but the costs may well outweigh the benefits, not least because of the likelihood of leaks and the speculative press interest in such an exercise making the chances of keeping it private slim.

5 Scavotto and Skinkle (2013).

6 Reverse stress testing is an additional area of fertile ground where private reverse stress tests might reveal hidden concentrations or structural weaknesses in the global financial system. However, reverse stress testing is still in its infancy (despite being a requirement in the EU since 2010), and on a practical level such an exercise is somewhat distant.

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